

BULLETIN of the American Association of Petroleum Geologists

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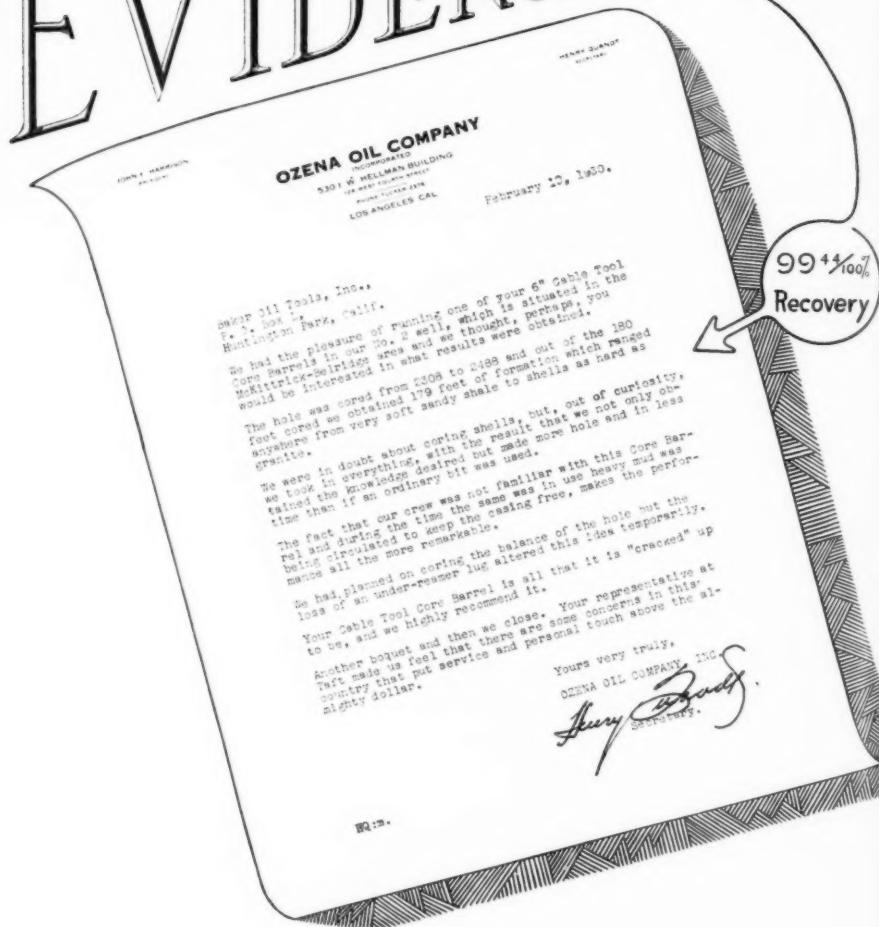
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BULLETIN
of the
**AMERICAN ASSOCIATION OF
PETROLEUM GEOLOGISTS**

FEBRUARY 1933

**ANCESTRAL ROCKIES AND MESOZOIC AND
LATE PALEOZOIC STRATIGRAPHY OF
ROCKY MOUNTAIN REGION¹**

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Denver, Colorado

ABSTRACT

Land areas existed in the general position of the present southern Rocky Mountains in Paleozoic time and reached their maximum development in late Pennsylvanian time. These "Ancestral Rockies" conformed to the position of the present mountains in only a part of their extent. The evidence for non-deposition instead of erosion lies in changing lithology and thicknesses from the centers of the basins shoreward and from parallel faunal changes.

The most important stratigraphic breaks are post-Permian and post-Triassic. It is not believed that any widespread hiatus exists between the Permian and Pennsylvanian.

Mesozoic time was essentially a period of denudation, the ancient Rockies having been practically base-leveled by the end of the Jurassic. Marine conditions prevailed throughout most of the Upper Cretaceous period, upward movement beginning in Pierre time or earlier and culminating in the making of the present Rocky Mountains in the Laramide revolution.

The logical sequence of events is most effectually deciphered by a combination of faunal evidence, kind of materials and their source, areal distribution of the formations, correlation of homogenetic as well as time equivalents, and diastrophism. Fossil evidence is most important except in non-fossiliferous strata.

INTRODUCTION

The existence of ancient positive elements in the general area of the southern Rocky Mountains has been known and discussed by geologists for many years. These discussions approached the subject from different angles and in many cases consisted only of remarks

¹ Presented before the Association at the San Antonio meeting, March 21, 1931. Manuscript received May 27, 1931; revised manuscript, June 27, 1932.

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arising from casual observations in connection with general geological work. The subject has been treated, however, from a more general viewpoint by Emmons (16),¹ Lee (23 and 25), Melton (31), Lovering (28), Ver Wiebe (44), Rich (37), Johnson (21), and Schuchert (39 and 40); although in several instances these writers included in their discussions only parts of the Rocky Mountain region.

In the following pages it is proposed to present a brief account of the pre-Cenozoic correlations in the Rocky Mountain region; also to outline the probable sequence of events from Mississippian to the end of Cretaceous time, taking into account the paleontological data, the position of the land areas, materials comprising the land areas, extent of depositional basins, orogenic movements, and the agents of distribution and sedimentation.

The writer is indebted to Glenn C. Clark, chief geologist of the Continental Oil Company, for permission to use measured geologic sections.

The conclusions set forth in this paper, especially regarding the geologic history of late Paleozoic and early Mesozoic time, are mainly the result of field observations and a study of sections measured in Montana, Wyoming, Utah, Colorado, New Mexico, and Arizona by the writer and by H. L. Baldwin, Jr., C. D. Beeth, W. Grant Blanchard, Jr., A. E. Brainerd, I. A. Keyte, Ben H. Parker, and E. F. Miller. The writer also desires to acknowledge valuable assistance from discussions with I. A. Keyte, John B. Reeside, Jr., A. E. Brainerd, R. Clare Coffin, John G. Bartram, Junius Henderson, and Alex. W. McCoy. Where not otherwise designated, paleontological data were furnished by I. A. Keyte.²

In addition to field observations, the literature of the Rocky Mountain region has been freely used in assembling stratigraphic data, more especially that relating to Mesozoic formations. Considerable data for the paleogeographic maps relating to the main seaways and land areas, aside from the Ancestral Rockies themselves, have been taken, with modifications, from previous works, and acknowledgment is made to the authors.

CORRELATIONS

During the process of gathering the data for this paper it was found that formation names which have long been applied to certain series

¹ Numbers in parentheses indicate references at end of paper.

² Professor Keyte died on May 29, 1931.

of beds, include much greater thicknesses and a greater span of geologic time in some localities than in others. Instances of this kind can be said to be the rule rather than the exception. Moreover, it is very evident that certain formations with the same name in different localities are homogenetic equivalents, though not, in their entirety, time equivalents.

Correlations of Pennsylvanian and Permian formations will be found at variance, in many instances, with past usage and are based on paleontological determinations by Professor Keyte supplemented by physiographic deductions by the writer.

More detailed results and the correction of present correlations must await further stratigraphic studies.

LOWER PENNSYLVANIAN

No earliest Pennsylvanian sediments are present in the Rocky Mountain region, although Brady (4) reports beds of Des Moines age in the lower Minnelusa of the Black Hills. Probably Des Moines time is represented also in the Amsden of northern Wyoming and the Quadrant of Montana, as the lower portion of each of these formations is of Chester age.

The terms "upper Pennsylvanian" and "lower Pennsylvanian" are used here in a broad sense, lower Pennsylvanian time ending with the beginning of rapid elevation of the Ancestral Rockies accompanied by correspondingly rapid denudation. Lower Pennsylvanian strata are not to be construed as including lowest Pennsylvanian and in most cases do not extend below the Cherokee.

The Hartville and Minnelusa formations (Sections 28 and 29, Fig. 4) are believed to contain both upper and lower Pennsylvanian beds. Their combined thickness is slight compared with that in other localities. They probably received no sediments from the Ancestral Rockies and the nearest land area at the northeast was so low that it furnished very little detritus. Sandstones in the upper part probably came from the west.

The Amsden of Wyoming, aside from the Chester beds, probably contains only lower Pennsylvanian sediments. It is believed to be unconformable with the overlying beds in southern Wyoming. Much of it was eroded away and probably the entire formation was destroyed in the southern Laramie Mountains, where later Pennsylvanian rocks lie on the pre-Cambrian complex. The Quadrant of Montana is essentially the equivalent of the Amsden except that in

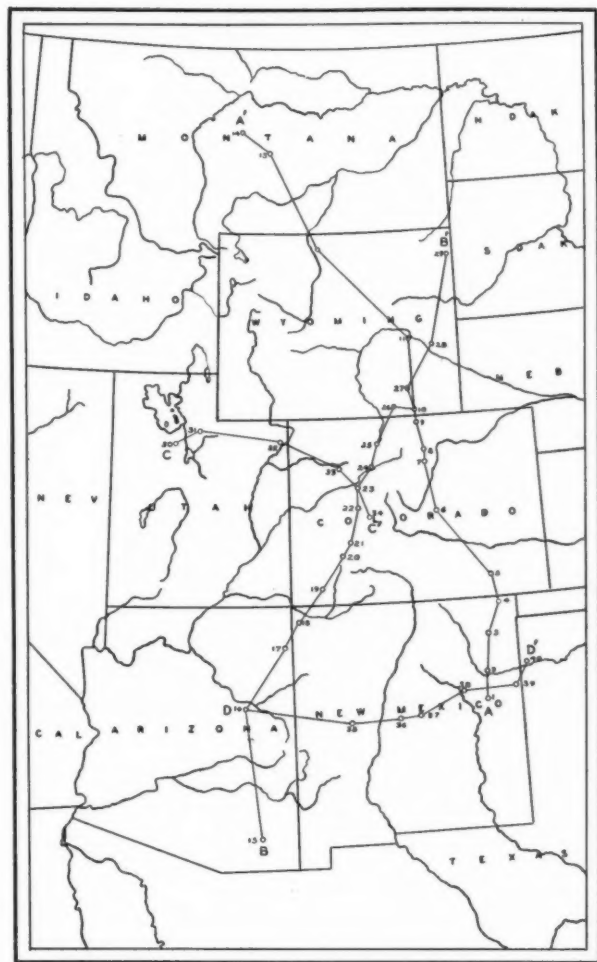


FIG. 2.—Index map to cross sections AA', BB', CC', and DD' of Figures 3, 4, 5, and 6.

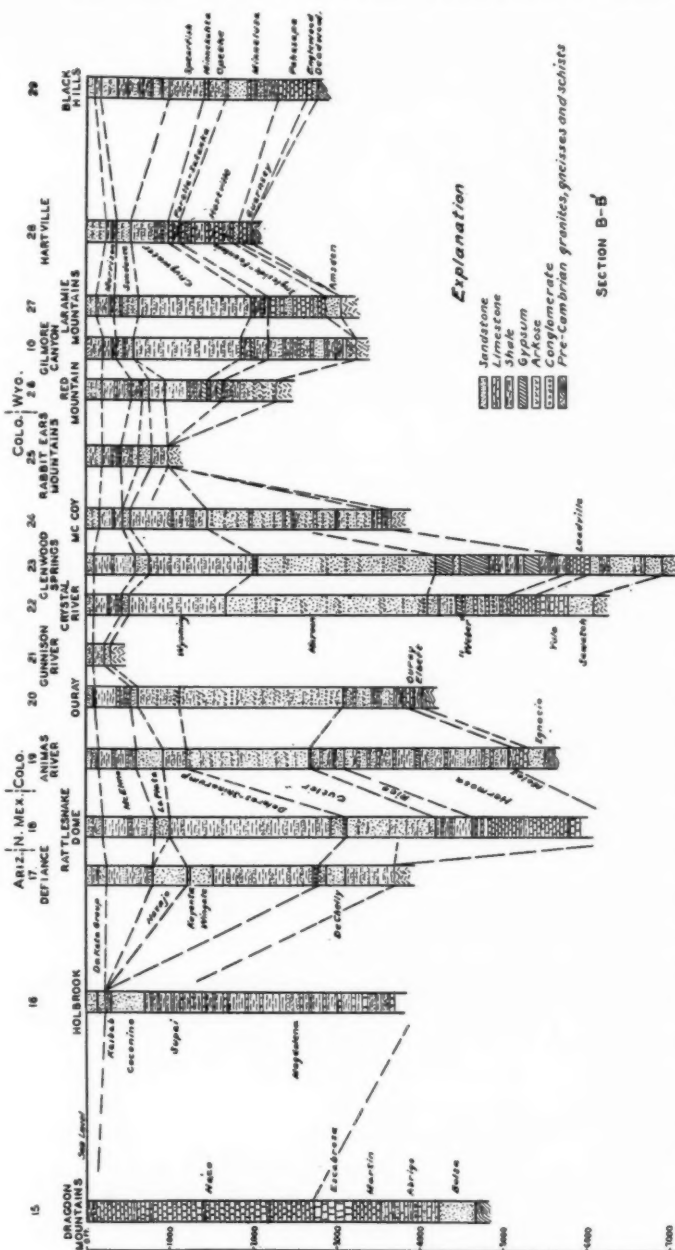


FIG. 4.—Correlation of Paleozoic and early Mesozoic formations from Dracon Mountains, Arizona, to Black Hills, Wyoming. Length of cross section, approximately 980 miles.

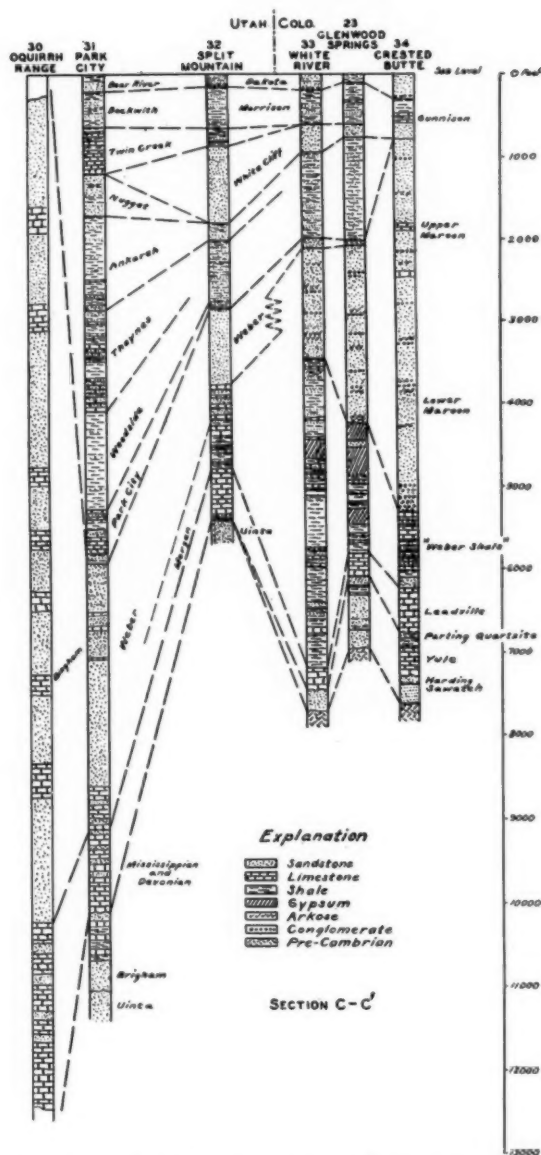


FIG. 5.—Correlation of Paleozoic and early Mesozoic formations from Oquirrh Range, Utah, to Crested Butte, Colorado. Length of cross section, approximately 350 miles.

some localities, beds equivalent to the Tensleep of northern Wyoming are included in the Quadrant (Fig. 3, sections 12 and 13).

The lower Fountain formation and the underlying Glen Eyrie of the Colorado Springs district are of lower Pennsylvanian age (Fig. 3, section 6). Their relation to the Fountain of other localities will be discussed under the heading "Upper Pennsylvanian."

The Veta Pass member of the Sangre de Cristo conglomerate is of lower Pennsylvanian age. It is on the opposite side of a Pennsyl-

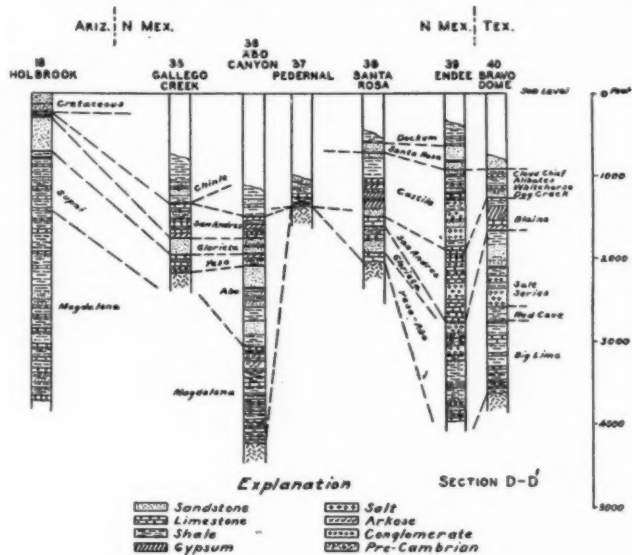


FIG. 6.—Correlation of Paleozoic and early Mesozoic formations from Holbrook, Arizona, to Bravo Dome, Texas Panhandle. Length of cross section, approximately 460 miles.

vanian land area from the lower Fountain and is not so directly comparable with it. The Veta Pass can be correlated as a unit with the Magdalena of central New Mexico from a paleontological standpoint, although the formations are dissimilar lithologically.

Beds of Cherokee age are present in the base of the Magdalena formation east of Taos, New Mexico, but in the majority of the sections measured in that state, the Magdalena probably does not extend below the Marmaton. The Magdalena is correlated with the Molas,

Hermosa, and Rico of southwestern Colorado, the Goodridge of southeastern Utah, the lower Naco limestone of southern New Mexico and the upper Tornado limestone of southern Arizona.

In the Grand Canyon district the lower Supai, as redefined by Noble (32, p. 59), is correlated with the Magdalena, although a considerable portion has been removed by erosion. The corresponding formation in southern Nevada is the Callville limestone.

In central Colorado the "Weber" shales¹ are correlated with at least the lower Magdalena of New Mexico. The upper limit of the lower Pennsylvanian is not so distinct. Due to the close proximity of this territory to relatively high land areas, the deposition of coarse material began in lower Pennsylvanian time and continued without interruption throughout Pennsylvanian and perhaps into Permian time. It is believed, however, that the "Weber" grits of the Ten Mile and Monarch districts and perhaps a part of the lower Maroon conglomerate of the Aspen district may be classed as lower Pennsylvanian.

The lower Pennsylvanian of north-central Utah is represented by the Weber formation. It is composed of light-colored sandstones or quartzites with interbedded limestone, the former predominating, and thickens rapidly from east to west. Beds believed to be the correlatives of the Weber in the Oquirrh Mountains attain a thickness of 9,000 feet and are called the Bingham Quartzite (5, Pl. V) (Fig. 5, section 30). The corresponding Wood River beds in central Idaho reach a thickness of 8,000 feet according to Umpleby, Westgate, and Ross (42, p. 29). The basal beds of the Wood River formation are conglomeratic.

The Weber in the Park City district is nearly 3,000 feet thick and in its upper part probably includes beds of upper Pennsylvanian age. The light-colored sandstones of the lower portion gradually disappear eastward, changing to a limestone and shale series, and at Split Mountain the strata to which the name Weber is applied consist of 1,000 feet of white-to-buff sandstone and probably belong in the upper Pennsylvanian (Fig. 5, section 32). It is possible, therefore, that all of the Weber of Split Mountain Canyon is younger than the Weber at its westernmost occurrence, where a considerable thickness has been removed by erosion.

The limestone, shale, and sand series of the Split Mountain section

¹ The "Weber" shales and overlying "Weber" grits of central Colorado constitute the "Weber" formation, which is not to be confused with the true Weber sandstone of northern Utah, the greater part of which is younger (Figs. 1 and 5).

is unnamed, but corresponds with the upper portion of the old "Wasatch" of the Uinta Mountains and in part with the Morgan formation of the Park City district. Similar beds of the same age are well exposed at the Cross and Juniper mountains in northwestern Colorado and occur also on White River, 45 miles farther southeast, where the section consists largely of black shales and gypsum with minor amounts of limestone and sandstone. These beds are correlated with the "Weber" shales and probably with the "Weber" grits of central Colorado. At McCoy (Fig. 4, section 24) the entire Pennsylvanian has been called the McCoy formation (38, p. 1265) and is composed largely of coarse sandstone and arkose, the lower part containing very fossiliferous beds of lower Pennsylvanian age.

The Wells formation of southeastern Idaho and southwestern Wyoming is similar to the Weber of adjoining areas in northern Utah in thickness and lithology (30, p. 72). The Tensleep of northern Wyoming is approximately equivalent to the Weber of northern Utah and its relationship to the Tensleep of central and southern Wyoming is similar to that between the Weber of the Park City district and the Weber of Split Mountain Canyon.

The Quadrant quartzite (9, p. 117) of Yellowstone Park is a counterpart of the Wells of Idaho, although it may contain older beds in its lower portion. The change from predominant sandstone and quartzites in that locality to limestones and shales in central Montana is comparable with that from the Weber of north-central Utah to the unnamed series (Morgan formation?) in northeastern Utah and northwestern Colorado. The Quadrant of central Montana includes lower Pennsylvanian and upper Mississippian beds.

UPPER PENNSYLVANIAN

In Figure 3, section 6, the Fountain formation is shown to be 4,500 feet thick. The lower part, together with the underlying Glen Eyrie, is of lower Pennsylvanian age, probably the equivalent of the Magdalena of New Mexico. In section 7 the Fountain formation is only 1,250 feet thick, and since its extreme upper part can be traced into the fossiliferous limestones of the Ingleside, which is very late Pennsylvanian, it is likely that the entire thickness of the Fountain at Boulder and Chimney Hollow is upper Pennsylvanian, and that it is equivalent to only the upper Fountain of Colorado Springs. The upper Pennsylvanian beds overlap the lower Pennsylvanian. The direction of outcrop along the eastern foothills of the Rocky Moun-

tains bears a little west of north from Colorado Springs to Boulder, and the ancient shore line extended more nearly north and south. Equivalents of the lower Fountain and Glen Eyrie at Colorado Springs are therefore probably present 25 or 30 miles east of Boulder under many thousand feet of younger beds.

The Ingleside formation as shown in Figure 3, sections 8, 9, and 10, thickens northward with a corresponding thinning of the underlying arkose and conglomerate of the Fountain formation. It is believed that most of the Ingleside at Gilmore Canyon is equivalent in age to the Fountain at Chimney Hollow. At La Bonte, Wyoming, typical Fountain material has been replaced by sandstones and marine limestones of the Ingleside formation (upper Casper).¹

The Sangre de Cristo conglomerate of the Sangre de Cristo Mountains, exclusive of the basal Veta Pass member, is 11,000 feet in thickness (21, p. 9) and is believed to be of upper Pennsylvanian age, although the deposition of this enormous thickness of coarse red beds may have continued into Permian time.

In Mora Creek Valley, New Mexico, 75 miles south of the Colorado line, there is a series of beds corresponding with the Sangre de Cristo conglomerate, though much thinner. Overlying the Magdalena, which also contains much coarse material, are 2,600 feet of coarse, red arkosic sandstones and conglomerates which are considered as the equivalent of the Abo formation farther south. These are overlain by 1,100 feet of finer-grained red beds, which are correlated with the Yeso, and they also contain some arkosic and conglomeratic material. At the top of the section is a bed of white-to-yellowish sandstone 200 feet thick, the equivalent of the Glorieta. The total thickness from the top of the Glorieta to the base of the Magdalena is 6,900 feet. The Abo has been classed as Permian, but it appears to be traceable into the upper Pennsylvanian portion of the Sangre de Cristo conglomerate and doubtless is correlated also with the upper Fountain of the Front Range.

The upper fine-grained red beds of the Mora Creek Valley section can also be correlated with the upper Sangre de Cristo and may be all Permian or part Pennsylvanian in age. They are believed to be equivalent to at least the lower portion of the Lykins formation of the Front Range. On the other hand, there is no proof that the Fountain of the southern Front Range does not extend into the

¹ The name "Casper" includes beds which are equivalent to the Amsden, Ingleside, and Tensleep formations of other localities.

Permian, inasmuch as the deposition of coarse material in southern Colorado and northern New Mexico probably continued longer than in northern Colorado. On the assumption that this were true, the Yeso and upper Abo may be placed in the Permian. The general equivalency of these formations is thought to be fairly well established, even though their exact age may be undetermined.

The Cutler of southwestern Colorado is correlated with the Abo of New Mexico and the discussion of the age of the Abo applies to it also. Equivalent finer-grained red beds in Utah and Arizona are represented by the Supai formation, except its lower portion in the Grand Canyon district, which is equivalent to the Magdalena. The Coconino of Utah and Arizona can be traced into the upper Cutler (1, p. 1420) and it is probable that red-bed deposition proceeded in southwestern Colorado while the Kaibab limestone was being deposited in the marine basin farther west. Since the Cutler formation is overlain by Upper Triassic strata, red beds of Kaibab age may have been removed by erosion if they were ever present.

The upper Pennsylvanian of central Colorado is believed to be represented by the Maroon conglomerate and its equivalents. From the great thickness in the Sangre de Cristo Mountains these beds thin north and northwest and disappear, as a lithologic unit, between the White River and Juniper Mountain sections of northwestern Colorado (Fig. 5, sections 32 to 34).

The upper Pennsylvanian of northern Utah is represented in the upper Weber and by the entire Weber of northeastern Utah and extreme northwestern Colorado. Both consist of light-colored sandstone. The greater portion of the Weber of Split Mountain Canyon is believed to be equivalent in age to the Maroon red beds of central Colorado (Fig. 5, sections 32 and 33). The 90 feet or less of white sandstone in the White River and Glenwood Springs sections represents a further spread of the Weber sandstone during a period when red-bed deposition from the Ancestral Rockies had practically ceased, at least temporarily. The age of this easternmost extension of light-colored sands may be upper Pennsylvanian or lower Permian.

Probably there are no upper Pennsylvanian beds in southeastern Idaho, southwestern and northwestern Wyoming, or central Montana. Some upper Pennsylvanian may have been deposited, but was removed by pre-Park City erosion. Farther east the deposits of light-colored sandstones were confined to the upper Pennsylvanian, while the lower Pennsylvanian consisted largely of marine limestones,

shales, and sandstones. Thus the Tensleep of central and southern Wyoming is wholly or in part younger than the Tensleep of the type locality in northern Wyoming, and the Wells of southwestern Wyoming is more nearly the equivalent of the Weber of northeastern Utah in the Split Mountain section.

Similar light-colored sands can be traced eastward in the upper portion of the Casper formation to the La Bonte section (Fig. 3, section 11) and to the upper Minnelusa of the Black Hills. Southward these sands are traceable into the Ingleside of the Laramie Basin and northern Colorado. Their relation to the upper Fountain formation has been discussed.

The lower Park City of southeastern Idaho and northern Utah and the lower Embar of northern Wyoming are classed as upper Pennsylvanian. They represent the beginning of a marine invasion from the west after a period of erosion and have no relation from a depositional standpoint to strata of other localities which may be of the same age.

PERMIAN

In many localities in the Rocky Mountain region the exact age of formations belonging about at the boundary between Pennsylvanian and Permian is in dispute. They are closely related and the correlation of some formations which may be Permian was necessarily mentioned in the discussion of upper Pennsylvanian.

The Lykins formation of the eastern Front Range includes a much greater interval of geologic time in the northern part of Colorado than in the central part (Fig. 3). At Colorado Springs the formation is only 200 feet thick, is probably all of Permian age and lies on the Fountain. At Boulder the thickness is 950 feet and the Lykins is separated from the Fountain by the Lyons, which is 200 feet thick and consists of cream-colored and pink sandstone, remarkably cross-bedded, especially in its upper portion. In following this formation north from Lyons, the type locality, the writer found stringers of red shale in the Lyons sandstone, increasing in number and thickness northward until at Ingleside the formation is predominantly red shale and sandy shale. The upper cross-bedded portion of the Lyons persists, however, and is called by Butters (6, p. 76) the "Cross-bedded sandstone" of the Lykins. It is obvious that Butters included in the Lykins, at this locality, beds which are equivalent to the Lyons farther south. Just north of Ingleside at Owl Canyon (Fig. 3, section 9) the "Cross-bedded sandstone" is 20 feet thick and is underlain by 325 feet of

red beds. Above the "Cross-bedded sandstone" and separated from it by a few feet of red shale is a bed of white gypsum 35 feet thick. Next above are 80 feet of red beds overlain by the "Crinkled limestone" which is believed to be the equivalent of the Forelle limestone of the Laramie Basin and the Minnekahta of the Black Hills. The 830 feet of red beds overlying the "Crinkled limestone" at Owl Canyon are also included in the Lykins and are correlated with the Chugwater of Wyoming which is classed as Lower Triassic. The "Cross-bedded sandstone" persists to the Wyoming line and perhaps a short distance beyond, where it feathers out into the Satanka shale. This formation includes everything from the Ingleside to the Forelle limestone and therefore includes the stratigraphic equivalents of the Lyons sandstone plus that part of the Lykins between the "Cross-bedded sandstone" and the "Crinkled limestone."

If the Satanka is Permian, it follows that the Lyons is Permian also. Butters (6, p. 84) places the lower Lykins in the Pennsylvanian.

The equivalent of the Lykins is doubtless represented in the upper Sangre de Cristo conglomerate of southern Colorado and it is correlated in a general way with some portion of the upper Yezo and Glorieta formations. The San Andres may represent the same period of sedimentation that was responsible for the deposition of the "Crinkled limestone" of the Front Range, but the evidence for this is mainly in its general stratigraphic relations.

From central to eastern and southeastern New Mexico there are red beds above the San Andres which are not known to be represented in the remainder of the Rocky Mountain region. These are the Castile beds which are placed by Gould and Willis (19, p. 438) as equivalents to the Dog Creek, White Horse, Alibates, and Cloud Chief of the Texas Panhandle.

The San Andres limestone and the Glorieta sandstone of New Mexico are correlated with the Kaibab and Coconino of Arizona, with the reservation that the entire thicknesses of these formations are probably not exact time equivalents. The Yezo is considered as the equivalent of the upper Supai of Arizona and the upper Cutler of southwestern Colorado, although there are beds in the upper Cutler which are higher than Yezo and equivalent in age to the Coconino.

The Coconino is correlated in a general way with the Weber of northwestern Colorado and the upper Weber of northeastern Utah, but is younger than the greater portion of the beds to which the name Weber is applied in north-central Utah. Similar strata, lithologically,

extend into the lower Pennsylvanian of this locality. The same holds true for the Tensleep of northern Wyoming, although the Tensleep of southeastern Wyoming and the upper sands of the Ingleside of northern Colorado are the homogenetic equivalents of the Coconino and are little older, if any.

The Kaibab is believed to be correlated essentially with the Phosphoria of southeastern Idaho, the upper Park City of northern Utah, and the upper Embar of Wyoming excluding the portion which has been separated out and called Dinwoody. The lower Park City and Embar are late Pennsylvanian.

In central Wyoming the Embar changes eastward from typical marine deposits to red beds, with which are associated gypsum and limestones (8). In some localities a portion of these beds has doubtless been included in the Chugwater. The red facies of the Embar with its included limestones and gypsum is correlated with the Forelle and Satanka of southern Wyoming and the Minnekahta and Opeche of the Black Hills. Gray sandy shales with streaks of red in northwestern Colorado, overlying the Weber sandstone, may be equivalent to the Park City.

LOWER TRIASSIC

The Lower Triassic is represented in the Black Hills by the Spearfish formation and in southern Montana and most of Wyoming by the Chugwater formation. The name is here used in its "restricted" sense (36, p. 58), excluding the Upper or Middle Triassic Jelm beds and the lower or Permian portion as originally defined by Darton (13, p. 397) at the type locality in southern Wyoming. The upper Lykins of the northern Front Range in Colorado doubtless contains beds equivalent to the Chugwater. The Dinwoody of the Lander district in Wyoming is traceable into the basal Chugwater of other areas.

The thickest formations of Lower Triassic age are the Thaynes limestone and Woodside shale of northern Utah, southeastern Idaho, and southwestern Wyoming. Equivalent beds in southern Utah, Arizona, and Nevada are represented by the Moenkopi formation.

UPPER TRIASSIC

Probably no Upper Triassic formations exist on the east side of the Front Range in Colorado nor in eastern Wyoming or Montana. They occur in central Wyoming as the Jelm or "Popo Agie" beds. In eastern New Mexico, the Upper Triassic is represented by the red beds of the Dockum group and by the Santa Rosa and Trujillo sand-

stones. This series is correlated with the Chinle red shales of western New Mexico, Arizona, and Utah, including the Shinarump conglomerate at the base.

The Upper Triassic is represented in southwestern Colorado by the lower part of the Dolores formation, in central Colorado by beds in the upper Wyoming, and in northwestern Colorado by an unnamed series of red beds which is correlated with the Ankareh shale of the Park City district and southwestern Wyoming. There is some confusion as to the use of the term Ankareh in southeastern Idaho, but possibly the Wood shale, Deadman limestone, and Higham grit are equivalent to at least a part of the Ankareh. These formations are placed doubtfully in the Triassic by Mansfield (29, p. 51) and they may bear a closer relationship to the Nugget and are possibly Jurassic. The Timothy sandstone, which underlies the Higham, is placed by Mansfield in the Lower Triassic without paleontological evidence, but since it is defined at its base by an unconformity, it may be Upper Triassic and thus correlated with the lower Ankareh.

JURASSIC

The lower series of beds here placed in the Jurassic is the Glen Canyon group of Gregory and Moore cited by Gilluly and Reeside (18, p. 68), who assign this group, with question, to the Jurassic. No distinctive faunal data are available and the position of these beds in the geologic column can be assumed only from the geologic history and the relationships to overlying and underlying strata. The Glen Canyon group of Arizona and Utah consists of the Wingate sandstone below and the Navajo sandstone above, separated by thin-bedded sandstones and limestones which have been called the Todilto (?) formation in recent publications. It has now been determined that the Todilto (?) beds are older than the true Todilto of Todilto Park, New Mexico, and the name Kayenta is being proposed by Baker, Dane, and Reeside to replace Todilto (?).¹

The Wingate is correlated with the upper massive sandstone of the Dolores formation of southwestern Colorado, and the Kayenta with the top thin-bedded sandstones of the Dolores. It is not known whether the Wingate occurs eastward in New Mexico and eastern Colorado, but there is a red massive sandstone in the upper part of the Lykins formation south of Colorado Springs which resembles very much the upper sandstone of the Dolores. A similar red sandstone

¹ Manuscript in preparation.

occurs near the top of the red beds in the Red Rock district of Purgatoire Canyon, in Las Animas County. These sandstones have always been considered as of Permian age, however. The white to salmon-colored, massive, cross-bedded sandstone in northern New Mexico, which is correlated with the Exter sandstone of the Cimarron Valley in northeastern New Mexico, is believed to be younger than the Wingate, although it is called Wingate by Darton (12, pp. 33 and 34).

The Navajo sandstone of Utah and Arizona is correlated with Coffin's lower La Plata (7) of southwestern Colorado, but is older than the typical lower La Plata of Cross (11) in the San Juan Mountains. It is probably the equivalent of the type Nugget (43, p. 56) in southwestern Wyoming, but not of the so-called Nugget of the eastern Uinta Mountains and northwestern Colorado, which is younger.¹

The Carmel formation of Utah is the equivalent of the lower portion of the Twin Creek at its type locality in southwestern Wyoming and of the Ellis formation of Montana.² The limestone member beneath Coffin's upper La Plata in southwestern Colorado probably occupies about the same position. The Entrada sandstone, which overlies the Carmel in Utah, is correlated with the type lower La Plata of the San Juan Mountains (Coffin's upper La Plata), with the so-called Nugget or White Cliff of the eastern Uinta Mountains and northwestern Colorado, and with the lower member or "Sundance sand" of the Sundance formation of Wyoming.

In northern and northeastern New Mexico there occurs beneath the Todilto limestone and above the Triassic red beds, a cross-bedded sandstone which resembles in lithology the sandstones farther west which are assumed to be of eolian origin. It is white, pink, salmon-colored and light red in color and is called Wingate by Darton, who regards it as bearing conformable relationships to the overlying Todilto (12, p. 33). There seems to the writer to be some doubt as to the equivalency of this sandstone to the Wingate. The limestone and gypsum of the Todilto appear to lie conformably upon it at every locality examined. There seems to be no stratigraphic break which could not be accounted for by the abrupt change from eolian to marine or fresh-water conditions. The lower contact with the red beds is wavy, and in some localities, such as in the valley of the Dry Cimarron in the northeastern corner of New Mexico, this sandstone lies with an angular unconformity on the red beds. At its easternmost

¹ John B. Reeside, Jr., personal communication.

² *Idem.*

occurrence, in the Oklahoma Panhandle, it fills cavities and channels in the underlying shales.

The limestone and gypsum of the Todilto formation are at least as young as Curtis and perhaps younger, and its contact with the underlying sandstone, if the latter is Wingate, must represent an interval equal to at least the Kayenta, Navajo, Carmel, and Entrada. Since there is probably not a gradational overlap of this magnitude, and since the sandstone bears a closer lithologic resemblance to the La Plata group and to the basal sandstone of the Sundance than to the Wingate, it is believed that it belongs higher in the section than the Wingate or its equivalent, the upper massive sandstone of the Dolores formation.

The exact relationships of the massive sandstone occurring in northern and northeastern New Mexico beneath the Todilto, to the Exter sandstone of southeastern Colorado and to similar sandstones farther north along the Front Range, are uncertain, but it seems desirable to consider the evidence at hand. The Exter occupies the same position and apparently bears a relationship to the overlying limestones and gypsum of the Morrison formation, similar to that between the eolian sandstone of northern New Mexico and the Todilto; similar also to the relationships between the Sundance sand of northern Colorado and the limestones of the lower Morrison. At many points along the Front Range a massive sandstone, white, yellow or orange-colored, is present at the base of the Morrison formation. Hills (20, p. 1) describes the lower Morrison in the Walsenburg quadrangle as consisting of "about 60 feet of soft white sandstone." The log of the well drilled by the Union Oil Company of California a few miles southwest of Pueblo shows 55 feet of white sandstone at this horizon and the writer found about the same thickness cropping out near Beulah. Finlay (17, p. 7) mentions "fine grained friable sandstone at base [of Morrison], overlain by fresh water limestones" in the Colorado Springs area. Lee (24, p. 27), in reference to Turkey Creek Canyon southwest of Denver, says that

above the red beds is a yellow sandstone which may represent either the Jelm formation, of late Triassic age, or the lower sandstone of the Sundance formation of late Jurassic age.

He shows (24, p. 28) in a measured section at Morrison, 0 to 17 feet of massive pink to yellow sandstone at the top of the Lykins or at the base of the Morrison. At Bear Canyon south of Boulder, he mentions (24, p. 31) "30 feet of 'soft, white, massive sandstone' that probably

represents the lower part of the Sundance formation" and at Lyons his measured section (24, p. 32) shows 35 feet of yellow and orange cross-bedded sandstone. In a measured section at Cottonwood Canyon, Lee (24, p. 33) shows 15 feet of yellow, even-bedded sandstone underlain unconformably by orange massive sandstone 25 feet thick. At Owl Canyon the writer has measured 120 feet of pink and salmon cross-bedded sandstone.

It is fairly certain that the beds designated by Lee as possibly belonging to the *Jelm* are Jurassic in age and that no Upper Triassic beds exist in northern Colorado. The massive sandstone is placed with little hesitancy by Reeside (35, p. 1102) as equivalent to the *Entrada* and to a part of the Upper Jurassic Sundance formation of Wyoming, a supposition with which the writer is entirely in accord. There is a possibility, however, that this sandstone does not disappear entirely southward as Reeside indicates (35, p. 1100), but that the sandstones which occur at the base of the *Morrison*, at the various locations cited, may be equivalent to the lower member of the Sundance formation and that they may be correlated with the *Exter* of southeastern Colorado and the so-called *Wingate* of northern New Mexico. The writer believes that these sands were of eolian origin and that they came from the west. The ancient Carboniferous highlands of the Rocky Mountain region had been nearly base-leveled by late Jurassic time, but there was probably an area extending from northern New Mexico northward to a point in Colorado 35 or 40 miles west of Boulder which was slightly higher than the surrounding territory and presented a partial barrier to the eastward movement of the dune sand. It would be natural to expect, therefore, that the sandstones, if present at all on the east side of the barrier, would be thinner than at the north and south and that they might easily be spotted or absent entirely in considerable areas.

On the other hand, it is significant that the massive sandstone is divisible into two parts in some of the northern Colorado sections, with an unconformity between in the Cottonwood Canyon section. It is conceivable that the lower division or the Sundance sandstone may disappear southward and that the upper division, which could properly be placed in the *Morrison*, continues intermittently in that direction. The *Exter* may, under this interpretation, also be correlated with a portion of the *Morrison*, as may also the so-called *Wingate* of northern New Mexico.

Another possibility is that the so-called *Wingate* of the Las Vegas

area is not the equivalent of the Exter nor of the basal Morrison sandstones of the central Front Range in Colorado.

The writer believes that the so-called Wingate of northern New Mexico is older than Morrison and younger than Wingate for reasons cited. Since the Navajo of Arizona pinches out eastward before reaching New Mexico,¹ and since the lower La Plata is exceedingly widespread in its occurrence and is identical in lithology and stratigraphic position with the New Mexico sandstone, the writer considers that the preponderance of evidence favors the correlation of this sandstone with the lower La Plata or Entrada.²

The Sundance marine beds of Wyoming are equivalent to the upper Twin Creek of the type locality in southwestern Wyoming (43, pp. 56-57) and of the entire Twin Creek of the eastern Uinta Mountains and northwestern Colorado.³ They are correlated with the Curtis and probably the Summerville of central Utah. Marine beds equivalent to the Curtis extend through a considerable area in northwestern Colorado and conformably overlie the Entrada sandstone or its equivalent. Above the marine beds there is a series of gray shales and limestones, the latter yielding algal remains and fresh-water gastropods, all Morrison species, as noted by Reeside (35, p. 1101). He also says that "southward the marine zone disappears and then the Entrada itself, leaving the limestone zone of the Morrison directly on pre-Jurassic rocks." The Entrada sandstone does disappear southward, but it is very possible that this is a result of the approach toward the old "San Luis" positive element on which the sandstone was never deposited and that it may encircle this high area at the south and east and be continuous with the similar sandstone in the Chama Basin and farther-east in New Mexico (12, p. 167).

In eastern Colorado, along the Front Range, fresh-water limestones in the base of the Morrison are described by Reeside (35, p. 1102) as having a similar sequence and fossil content to those in western Colorado. No marine zone could be identified in the eastern area, however. The fresh-water beds lie directly on the basal Sundance sand or Entrada and it was this relationship, together with the association of bedded gypsum with the limestones at many localities, which led Lee (23) and Logan (26) to the belief that these beds were of Sundance

¹ John B. Reeside, Jr., personal communication.

² Reeside believes that the Exter is either Wingate or Morrison and that probably the same is true of the so-called Wingate of northern New Mexico. Personal communication.

³ John B. Reeside, Jr., personal communication.

age and, as described by Lee, "represent the extension of the Jurassic sea beyond the localities where its waters were suitable for the support of marine organisms." Inasmuch as the marine and fresh-water facies occur together in northwestern Colorado and other places, it seems likely that the latter comprise a direct correlative of the basal Morrison beds of eastern Colorado and the Todilto of New Mexico and that the contact of both series with the underlying sandstone is gradational, as stated by Reeside (35, p. 1101). He also states, on the same page, that the boundary between the marine and fresh-water beds is only arbitrary. It is evident that there is a close relationship between the Sundance and lower Morrison and, in the writer's opinion, it is very difficult to explain the widespread occurrence of thick deposits of bedded gypsum in Utah, New Mexico, southeastern Colorado, and other localities, without recurrence to the marine hypothesis.

The McElmo formation of southwestern Colorado is correlated with the Morrison, although it is much thicker and contains massive sandstones in its lower part. Associated with these sandstones in some localities are non-fossiliferous limestones and gypsum, which may occupy the same stratigraphic position as the Todilto and lower Morrison of other localities. No marine Jurassic beds are present in southwestern Colorado. The Zuni sandstone of the Zuni Plateau is correlated with the lower McElmo sandstones. McElmo, as used by various authors, includes a greater stratigraphic interval in some localities than in others. The lower Beckwith of southwestern Wyoming is considered the equivalent of the Morrison.

LOWER CRETACEOUS

The Fuson shale and Lakota sandstone of the Black Hills are correlated with the Cloverly of Wyoming and the Kootenai of Montana. Beds of this age may be present in the lower members of the "Dakota" sandstone of the western slope of Colorado and perhaps in the basal sandstone and conglomerate of the "Dakota group" in southern Colorado. Northward, according to Lee (24, p. 20), a shale apparently divides the lower sandstone member and is correlated with the Fuson.

The upper shale member in northern Colorado is correlated with the Glencairn shale of the Purgatoire in southern Colorado, and probably with the Skull Creek shale which, in the Black Hills, lies between the Newcastle sandstone and the Fall River sandstone (Dakota of Darton).¹ The Fuson and Lakota are thus considered older than the

¹ John B. Reeside, Jr., personal communication.

Purgatoire. The Kiowa shale and Cheyenne sandstone of western Kansas are correlated with the Purgatoire.

UPPER CRETACEOUS

The upper member of the "Dakota group" is classed as Upper Cretaceous in the areas where the lower members are of Washita age. Since the deposition of all of the sandstones was accomplished during the gradual encroachment of the sea, the formations were necessarily older in areas first submerged than in those covered by the extreme limits of the depositional basin; it is, therefore, probable that the entire "Dakota group" in Utah, for example, may be as young as, or younger than the upper sandstone of central Colorado. It is entirely plausible to assume that the dark shales of the Benton formation were being deposited in eastern Colorado concurrently with the upper "Dakota" of Utah and western Colorado. The Bear River of southwestern Wyoming is thought to contain equivalents to the "Dakota group."

By "Dakota" time the Ancestral Rockies had been base-leveled, except that there may have been a few small areas in central Colorado where no "Dakota" was deposited (28, p. 89). The whole area sank beneath the sea in Benton time and, except for temporary shoaling, remained so until near the end of the Upper Cretaceous. The history of the Ancestral Rockies thus comes to a close and no need arises in this connection for a correlation of the remainder of the Upper Cretaceous formations.

PALEOGEOGRAPHY

Geologic processes of the past were so complex and extended over such an immense period of time that it is impossible to indicate on a map the exact relationship of erosional and depositional areas at any one time over an extensive area.

The perusal of any series of paleogeographic maps will therefore leave the impression that a fairly simple succession of events has led to the present configuration of the continent. The observer must bear in mind, however, that only a few of the more important situations can be shown and each map may attempt to show a general summary of results throughout a long period of time or perhaps give a picture, as nearly as possible, of the maximum extent of the land or water at one epoch in the earth's history. It must be remembered that innumerable changes took place which are not recorded and also that enormous lapses of time intervene between the fractional periods or epochs shown by the maps.

PRE-PENNSYLVANIAN

Due to the nature of the sediments deposited in the Rocky Mountain region in pre-Carboniferous time and to the many orogenic movements and erosion intervals, the relations of land and sea are not so readily deciphered as in the late Paleozoic. However, it is fairly certain that positive elements have existed in the region since pre-Cambrian time. Most of the area has been intermittently above and below sea-level but some portions have doubtless been land continuously until the beginning of Upper Cretaceous.

The most widely distributed Mississippian formation in the Rocky Mountain region is the Madison limestone, of early Mississippian age. It was doubtless deposited over practically all of the northern part of the region, but land masses existed in Colorado in the region of the Ancestral Rockies, as indicated by the sandy nature of the sediments and by their overlap on the Ordovician and pre-Cambrian rocks (28, p. 79). The Madison was probably removed from a large area in the Front Range of Colorado, where upper Pennsylvanian beds lie on pre-Cambrian granite and contain Mississippian fossils in chert pebbles at the base. The absence of Mississippian formations in northern New Mexico is believed to be due to non-deposition for the most part.

Late Mississippian (Chester) strata are known in southern New Mexico and Arizona and in Montana and northern Wyoming, but insufficient evidence is at hand to determine the extent of their original deposition.

EARLY PENNSYLVANIAN

Earliest Pennsylvanian time is not represented in the Rocky Mountain region, but rocks as old as the Bend series of Texas were determined to be present in northeastern Utah, northwestern Colorado, northern Wyoming, and Montana.

Cherokee time is represented in some sections of the Magdalena in New Mexico, in the Amsden of Wyoming, the Minnelusa and Hartville of eastern Wyoming, the "Weber shales" of central Colorado, the Morgan formation of northwestern Colorado and northern Utah, and the Glen Eyrie of the eastern Front Range in Colorado.

At least a part of Marmaton time was evidently represented by a considerable amount of erosion over north-central Colorado and as far north as central Wyoming, if not over a large part of the Rocky Mountain region. It resulted in the removal of a portion, and in places perhaps all, of the earlier Pennsylvanian sediments. This erosional un-

conformity is shown in the lower part of the Minnelusa of the Black Hills. It is evidenced also by the absence of the Amsden in a large part of Wyoming and by the absence of Marmaton beds in eastern Colorado and the Panhandle of Oklahoma (38, p. 1278).

Figure 7 shows the general relationships of land and water from the beginning of Pennsylvanian deposition in the Rocky Mountain region until the end of Kansas City time. The connection with the sea was at the south and southwest.

The land areas are given the names "Front Range," "San Luis," "Zuni," and "Defiance" for convenience. The two small areas in Utah, not named on the map, may be called "Circle Cliffs" and "San Rafael." The name "Amarillo Mountains" is in common usage for the buried granite ridge of the Texas Panhandle, and the southern end of the "Front Range" may be appropriately designated as "Pedernal." The main land area on the northwest is called "Cascadia," after Schuchert (39).

Sedimentation around Ancestral Rockies.—The map (Fig. 7) shows the areas in which no older Pennsylvanian beds are thought to exist and on which, for the most part, none was deposited. The actual line of overlap is obscured along the east side of the "Front Range," except near Colorado Springs, where there are local exposures of the Glen Eyrie formation. At other points the Fountain or equivalent beds which doubtless belong mostly in the upper Pennsylvanian, are in direct contact with pre-Cambrian rocks. This holds true also in Wyoming to a point on the east side of the Laramie Mountains 45 miles north of the Colorado line, where a series of beds, probably corresponding with a part of the Amsden formation, occur in contact with the granite and display a sharp contrast in lithology to the overlying Ingleside beds. Hard red sandstones and shales make up these lower beds, and the Ingleside consists of massive light-colored limestones and shales. Both together constitute the Casper formation of this locality.

In southeastern Colorado and northeastern New Mexico the relationships of land and water in early Pennsylvanian time are shown rather unsatisfactorily by well logs but they are believed to be essentially as shown on the map. An account of the probable existence of a buried granite ridge in this locality was published by Rich (37) in 1921. In the Pedernal Hills pre-Cambrian rocks are exposed, surrounded by overlapping Permian or upper Pennsylvanian red beds. It is not known how closely Magdalena beds approach these hills on

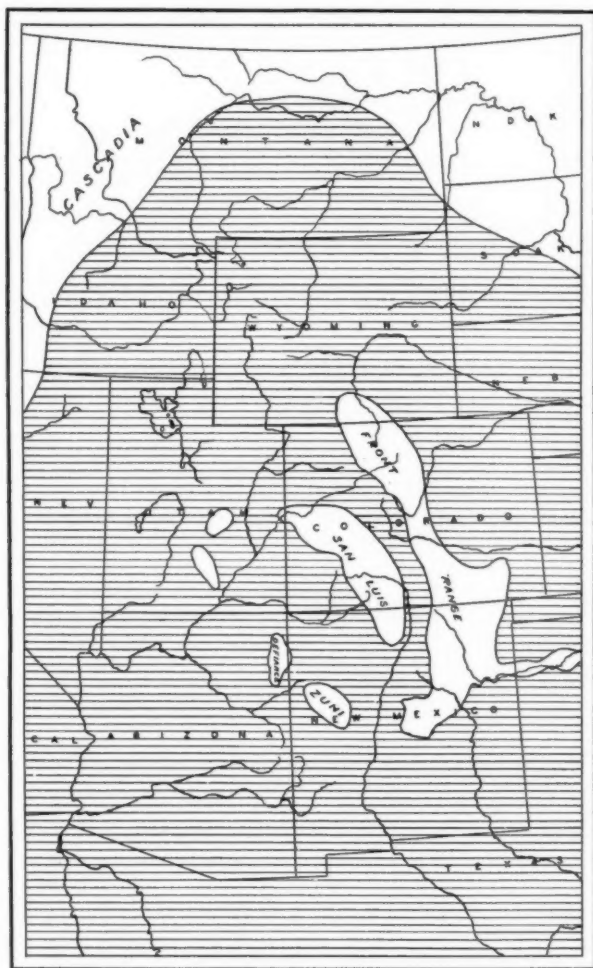


FIG. 7.—Paleogeography of lower Pennsylvanian: upper Quadrant, Wells, lower Tensleep and upper Amsden, lower Weber and Morgan, Bingham, Minnelusa, Hartville, "Weber shales and grits," lower Fountain-Glen Eyrie, Magdalena, Goodridge, Hermosa-Molas, lower Supai, Callville, upper Tornado, lower Naco. Ruled areas are marine basins of deposition.

the east, but they occur in considerable thicknesses in Estancia Valley on the west.

Along the west side of the "Front Range" the zone of overlap of Mississippian and early and late Pennsylvanian on pre-Cambrian rocks is narrow. Higher beds up to the Upper Cretaceous lie on granite on various portions of the "Front Range" element.

The overlap of early Pennsylvanian sediments on pre-Cambrian rocks is obscured by later beds around "San Luis" and the actual position of the ancient shore line can not be ascertained. Triassic and Jurassic formations lie on pre-Cambrian rocks and also at many places on the upturned edges of the Pennsylvanian. It is therefore evident that the land area of "San Luis" could very well have been more restricted than the map shows and that considerable areas of the Pennsylvanian were removed in later time. This is suggested especially by the nature of the sediments at outcrops nearest the north-western part of "San Luis" which are fine grained and non-red. This does not entirely preclude the possibility of near-by land areas, however, since it is very probable that this portion of "San Luis" was low and incapable of furnishing coarse sediments.

Neither the Magdalena beds nor their equivalents are thought to be present on "Zuni," "Defiance," "Circle Cliffs," "San Rafael," or the "Amarillo Mountains." Moreover, it is not known how close early Pennsylvanian beds approach these elements.

The assumption that land areas existed as shown on the map and that the absence of Pennsylvanian sediments is due to nondeposition rather than erosion, is based on the changes in lithology from a predomination of limestones, shales, and fine sandstones to coarser sandstones, arkoses, and conglomerates as the positive elements are approached. Within certain limits thickening occurs in that direction also.

The term "Ancestral Rockies" is inappropriate in so far as concerns its application to the positive elements here designated by that name. The impression is given that they may have been high mountains, but it is more likely that they were low land areas throughout the greater part of their history. Some portions of them may have attained considerable elevation during late Pennsylvanian and Permian time. In early Pennsylvanian time they were low with probably a relatively featureless aspect, although some parts of them were at times considerably higher than others. The surface was made up of both earlier Paleozoic sediments and pre-Cambrian rocks. Higher parts of the land areas existed on the northeastern side of "San Luis" with the

highest portion approximately on the present site of San Luis Valley. The highest parts of the "Front Range" were along its western side in central and southern Colorado and extending into northern New Mexico. The smaller positive elements in New Mexico, Arizona, and Utah were lowlands and it is possible that during a part of Hermosa time "Circle Cliffs" and "San Rafael" were submerged.

It is believed that the upward movement of the Ancestral Rockies, accompanied by erosion and the sinking of the adjacent depositional basins, was very slow at first but later increased in rapidity. Lower beds in the Pennsylvanian are entirely fine grained, even in close proximity to the shore lines, and their constituents were probably derived from the destruction of older sediments. As pre-Cambrian rocks became uncovered in local areas, the adjacent sedimentary basins received materials of coarser texture containing feldspars and other minerals originating from the granites, gneisses, and schists. The Glen Eyrie of the eastern Front Range and the "Weber" shales of the west side are examples of the earlier sedimentation, while the later deposits comprise the lower Fountain arkose and conglomerate and the "Weber" grits.

On the land areas of southeastern Colorado and northeastern New Mexico, pre-Cambrian rocks were exposed after the erosion of early Paleozoic sediments. The positive elements were never high, but furnished some arkosic material, as shown by the logs of wells in the Oklahoma Panhandle (38, p. 1277). In a well¹ on the Las Animas uplift in southeastern Colorado, a dark red or purple slate was encountered at 1,100 feet immediately under red beds of Permian or late Pennsylvanian age. The slate is probably pre-Cambrian. On the east edge of the uplift granite was reached at 1,860 feet.² Fifteen miles farther northeast a well was still in sedimentary rocks at 6,084 feet,³ having passed through a section of non-red Pennsylvanian nearly 2,000 feet thick and ending in beds of Ordovician age. Northward this buried ridge becomes lower so that lower Pennsylvanian was deposited over it. Its presence is expressed structurally in the Las Animas arch (Sierra Grande uplift in New Mexico).

Lower Pennsylvanian beds probably did not extend over the "Amarillo Mountains," but are present on the flanks as limestones, shales, and arkose or "granite wash" of probable Magdalena age.

¹ The Texas Company and Phillips Petroleum Corporation's Haskins No. 1, Sec. 23, T. 29 S., R. 56 W., Las Animas County, Colorado.

² Marland Production Company's Mesa No. 1, Sec. 8, T. 30 S., R. 50 W., Colorado.

³ Continental Oil Company's Pipe Springs No. 1, Sec. 27, T. 27 S., R. 49 W., Colorado.

The north end of the "Front Range" was low and furnished comparatively small amounts of clastic sediments, the Amsden being characterized by red shales and sandstones as well as fossiliferous limestones and non-red shales. The Amsden of northern and central Wyoming, as well as the lower Hartville and lower Minnelusa of eastern and northeastern Wyoming and the Quadrant of central Montana, are comparatively thin. They probably derived their clastic beds, mostly non-red, from the lowlands of the Canadian shield at the northeast. The sections also contain much fossiliferous limestone.

In the narrow trough between the "Front Range" and "San Luis" in southern Colorado and northern New Mexico, the Veta Pass member of the Sangre de Cristo conglomerate and the Magdalena formation contain a large percentage of arkose and conglomerate, mostly red, together with fossiliferous limestones and shales. In northwestern Colorado, where this trough widens, the coarse materials are found in the lower Pennsylvanian only near the margins of the basins as in the lower McCoy formation at McCoy on the northeast and in the "Weber" or Morgan (?) formation on the southwest margin on Crystal River and at Crested Butte. In the Glenwood Springs and White River sections, in the center of the basin, the sediments are predominantly black shales, with some limestone, very little sandstone, and no coarse material or red beds. In the later stages, this basin was evidently cut off from the open sea for long periods and conditions of evaporation prevailed, resulting in thick deposits of gypsum.

A similar basin existed southwest of "San Luis." At Ouray and on Piedra River, near the northeastern margin of the basin, the Hermosa formation contains considerable amounts of coarse arkosic sandstones, some of which are red. The proportion of coarse sediments is not so great as in the Veta Pass or "Weber" formations on the opposite side of "San Luis," because the higher parts of that land area were apparently on its eastern side. The Hermosa, on Animas River, 35 miles westward, is entirely non-red and is composed of sandstones, shales, and limestones, the latter predominating. The Hermosa is of similar nature in Paradox Valley and near Moab, Utah, at the northwest, although the proportion of black shales is greater. Here, as in the basin north of "San Luis," there are great thicknesses of gypsum and salt in the middle or upper part of the lower Pennsylvanian, and the cause of accumulation was doubtless the same. The southwestern margin of the basin was limited by the elements "Zuni," "Defiance,"

and "Circle Cliffs," with "San Rafael" on the northwest and "Pederal" on the southeast. The salt and gypsum deposits were confined to that portion of the basin near "San Luis." The Goodridge, of southeastern Utah and in the deep well in the Rattlesnake oil field of northwestern New Mexico, and the Magdalena, of north-central New Mexico south of "San Luis," have similar sections of limestone, shales, and sandstones in varying proportions, characteristic of shallow marine deposition not far removed from low land areas.

Another area of predominant black shale deposition, as shown by the logs of deep wells, existed southwest of "Defiance" in the vicinity of Holbrook, Arizona. The limestone percentage increases from that point southward until the Tornado formation in southern Arizona is practically 100 per cent limestone. The same conditions existed throughout the width of the Pennsylvanian sea in the southern part of the area, which was in the direction of the marine connection with the Pacific Ocean. Thus we find the Callville of southern Nevada, the lower Naco of southeastern Arizona and southwestern New Mexico, and the Magdalena of southern New Mexico almost entirely limestone.

Sedimentation from northwest.—"Cascadia," the land mass northwest of the Pennsylvanian epi-continental sea, furnished a vast quantity of sediments to the east, southeast, and south, covering western Montana and Wyoming, eastern Idaho, northern Utah, and northern Nevada. The land was relatively high and erosion was rapid, accompanied by continued elevation through a long period of time. Unlike the beds deposited around the Ancestral Rockies, the outstanding characteristic of these sediments is a great preponderance of white or light-colored quartz sandstones. They were deposited in marine water and contain marine limestones in subordinate amounts. Shales are practically absent in the sections nearest the shore line.

Since the thickness of these sands increases greatly toward the west and northwest, there is little doubt that their source was in that direction. The existence of such enormous quantities of clean white sand with practically no admixture of other clastic materials leads to the belief that the lands from which they were derived did not consist of the ordinary variety of granites, schists, and older sedimentary rocks. Large areas in western Montana are to-day occupied by thicknesses of Algonkian quartzite as great as 20,000 feet, with a composite of several measurements reaching a maximum of 37,000 feet (45). Eight thousand feet of Algonkian beds, mostly quartzite, exist

in central Idaho (42, pp. 29 and 30) and probably they extended also into western Nevada. It is believed that the great mass of white sands and quartzites of Pennsylvanian and later beds in the western Rocky Mountain region had their origin in the Algonkian quartzites at the northwest.

Deposition of light-colored sands along the western margin of the Pennsylvanian sea began in Mississippian time if not earlier. In the Oquirrh Mountains of north-central Utah they occur throughout the Pennsylvanian strata, which attain a thickness of 9,000 feet, an unknown thickness having been removed by erosion. In central Idaho, the Wood River formation is 8,000 feet thick and is essentially the same as the Bingham quartzite of the Oquirrh Mountains except that the basal beds are conglomeratic (42, pp. 29 and 30) and the pebbles are, for the most part, quartzite.

Light-colored sandstones were not distributed as far from the source of materials in the first stages of early Pennsylvanian history as they were later. In other words, they were confined to progressively higher beds from west to east. In the Park City district the Weber quartzite is nearly 3,000 feet thick, but it is underlain by the Morgan formation of different lithologic character, which seems to correspond with the Amsden of Wyoming. Eastward in the Uinta Mountains the lower Weber changes laterally, the quartzitic beds being gradually replaced by limestone, shales, and thinner-bedded sandstone, the change being progressively upward until all of the lower Pennsylvanian has lost its massive quartzitic character. At the Colorado line the Weber sandstone is 1,000 feet thick, but is probably all or nearly all later than Kansas City in age and is therefore classed with the upper Pennsylvanian of this paper.

The relations of the Wells formation of Idaho, the upper Quadrant of northwestern Wyoming and southwestern Montana, and the Tensleep of northern Wyoming to the Tensleep of southern and central Wyoming is analogous to that of the Weber of the Park City district, Utah, to the Weber of the northeastern part of the state. In southern Wyoming and a part of central Wyoming the succession of Pennsylvanian beds is different, the upper portion of the lower Pennsylvanian, —in some localities, all of it,—having been removed by erosion. Near the west end of the Casper Mountains, the Tensleep lies on Mississippian limestone. In the Laramie district, and in northern Colorado, the Ingleside and upper Fountain are in contact with pre-Cambrian rocks.

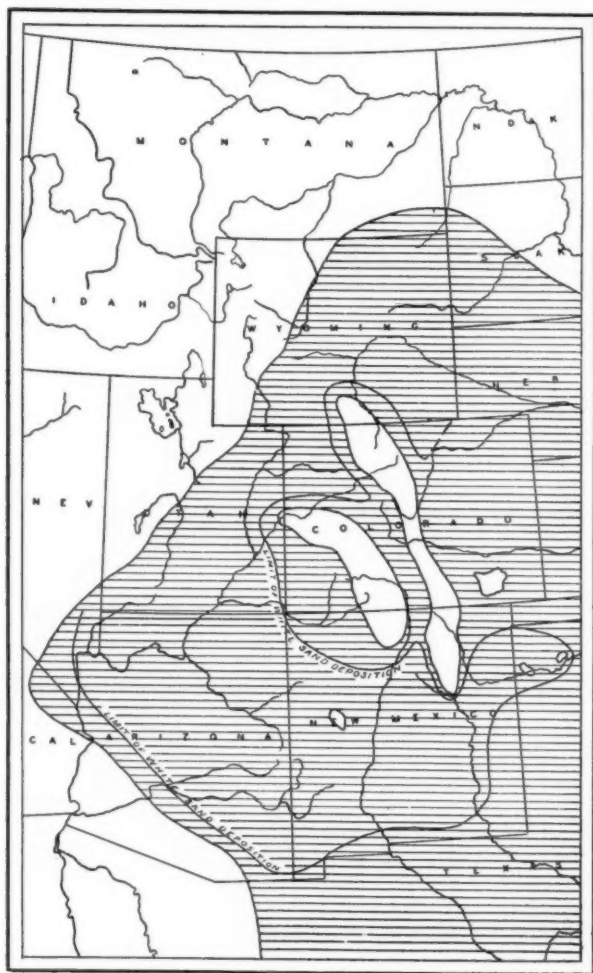


FIG. 8.—Paleogeography of upper Pennsylvanian and Permo-Carboniferous: upper Fountain and Ingleside, lower Lykins, upper Sangre de Cristo, Abo and Yeso, Glorieta, Supai, Coconino, Cutler, Maroon, upper Weber, upper Tensleep, upper Hartville, upper Minnelusa, upper Naco. Ruled areas are marine basins of deposition.

LATE PENNSYLVANIAN AND PERMO-CARBONIFEROUS

Upper Pennsylvanian time is here considered as including approximately the time from the end of Kansas City to the beginning of Wabaunsee time.

The spreading and depositing of certain upper Pennsylvanian sediments was unique and continued into Permian time, or at least into a period of which there is some doubt as to the exact age of the deposits. The term Permo-Carboniferous is therefore used. Figure 8 is intended to show the general relations of land and water in late Pennsylvanian time and perhaps a part of early Permian.

At the beginning of upper Pennsylvanian time, crustal movements which began in early Pennsylvanian were accelerated and the result was a greater differential between the highlands and the basins of deposition than had formerly obtained. Stream gradients increased and erosion was rapid. The surface of the Ancestral Rockies consisted mostly of pre-Cambrian rocks, and great thicknesses of coarse sands, arkoses, and conglomerates were deposited around the highlands. They were, in the main, near-shore and continental deposits. Since none of them was laid down in deep water, it is necessary to postulate a sinking basin and at the same time a land area rising with sufficient speed to furnish enough material for the great thickness of sediments deposited. If the rise in the land area had been more rapid than the denudation, the areas above water would have increased in size over those of the preceding period. However, the evidence seems to indicate that they had decreased in size, as shown by a comparison of Figure 8 and Figure 7. Early Pennsylvanian sediments were overlapped by later Pennsylvanian and early Permian.

The mainland at the northwest was also elevated, the shore line retreating southeast. A land area appeared in southern Arizona at about the same time, shifting the main seaward connection to the south and southeast. Most of the "Amarillo Mountains," the southern part of the "Front Range," and all except the southern part of "Zuni" were submerged and received sediments. "Defiance," "Circle Cliffs," and "San Rafael" had disappeared.

Application of theory of isostasy.—The history of sedimentation around the Ancestral Rockies, as interpreted from field evidence, appears to bear out, in part at least, the present generally accepted principles of isostatic compensation as they are summed up by Bowie (3, p. 247). Early Pennsylvanian would represent the earlier stages of uplift after a period of sedimentation.

In accordance with this theory, it might be said that the rise of the isogeotherms, which were depressed to positions below the normal temperature gradient during previous sedimentation and sinking, resulted in an elevation of the earth's surface by thermal expansion. Further elevation continued, due to physical and chemical processes, and uplift was more rapid than erosion until expansion had ceased. Obviously the mountains at that time had reached their maximum height, which in the case of the Ancestral Rockies was at the beginning of upper Pennsylvanian time, or coincident with the erosion and sedimentation of great thicknesses of coarse materials.

In latest Pennsylvanian, Permian, and subsequent time until the end of the Jurassic, the Ancestral Rockies continued to rise as a result of isostatic adjustments. The weight of eroded material deposited in the basins caused a sinking of these basins and a resulting horizontal movement of subcrustal material toward the land areas, causing them to rise. This upward movement was slower than the denudation, however, and the average elevation of the Ancestral Rockies above sea-level decreased. Base-leveling was accomplished near the end of Jurassic time.

On the assumption, according to Bowie (3, p. 257), that the density of subcrustal rock is 10 per cent greater than that of surface rock, when 1,000 feet of rock are eroded, it will require the movement of only 900 feet of subcrustal rock to maintain isostatic equilibrium. In other words "it will be necessary to erode 10 miles of material from the surface of an area one mile in average height in order to bring it to sea level." This seems to account for the enormous amount of material which was evidently derived from the comparatively small area of the Ancestral Rockies.

The same line of reasoning, although in the reverse order, can be applied to the sinking of the depositional basins. The sinking due to the weight of the sediments alone could not have proceeded to the extent that 20,000 or more feet of sediments were deposited in the trough between "San Luis" and the "Front Range." This area, no doubt having previously been an area of erosion, was subjected to thermal contraction and this contraction, while initiating the sinking of the area, continued until sedimentation had ceased.

On the other hand, conditions as interpreted from the present structure and distribution of sediments in the southern Rocky Mountains present various aspects which are not capable of adequate explanation by the simple application of the isostatic theory. There is

no evidence of excessive thicknesses of early Paleozoic sediments having been deposited in the areas later occupied by the Ancestral Rockies. On the contrary, there is evidence in some localities that positive elements have been present in the vicinity since pre-Cambrian time and that the sediments deposited around them were relatively thin.

The assumption that high mountainous areas have once been the sites of deep depositional basins and vice versa, seems to be substantiated in some places in the southern Rocky Mountains. The most notable example is the Sangre de Cristo Range, the highest continuous mountain chain in Colorado, which occupies the site of the ancient trough between the "San Luis" and "Front Range" elements. Pennsylvanian sediments up to 13,000 feet in thickness comprise a large part of the range and doubtless many thousand feet of younger sediments have been removed by erosion.

Trinidad basin is in an area which may have been a high part of the "Front Range" in Pennsylvanian time. Similarly, San Luis Valley now occupies the position of the highest part of ancient "San Luis." North Park, a structural basin, lies in the area of the northern part of the "Front Range." The La Plata and Needle Mountain uplift lies in a former deep basin of deposition off the southwest side of "San Luis."

On the other hand, the Denver basin is in a region of thick sedimentation, and a part of the present Rocky Mountain uplift appears to coincide with the location of a portion of the Ancestral Rockies. Moreover, although a portion of "San Luis" is now the site of San Luis Valley, its northwestern extension is now occupied by the Uncompahgre plateau, the rejuvenation of which evidently took place in the area of a Paleozoic positive element.

McCoy¹ maintains that the Ancestral Rockies were on pre-Pennsylvanian positive elements which controlled the paleogeography throughout Paleozoic time. He believes that the rejuvenation in late Pennsylvanian was due to a sinking of the surrounding basins, affording an increase in the rapidity of erosion and a resulting deposition of great thicknesses of coarse materials.

The subsequent burial of the Ancestral Rockies is ascribed by McCoy to the migration of the basin of deposition westward due to such uplifts as the Arbuckles, Wichitas, Llanos, and Glass Mountains. As for the present mountains, he believes that the only uplift

¹ Alex. W. McCoy, personal communication.

with reference to the center of the earth was the mountains themselves and that the high plains and plateaus around the mountains, which are now a mile or more above sea-level, were not uplifted at all. Their attitude is due to a shrinking and settling of the earth elsewhere and a reduction of sea-level.

Sedimentation around Ancestral Rockies.—The upper Fountain arkose and conglomerate were deposited east of the "Front Range." These beds probably extend only a short distance eastward under the plains formations, although equivalent finer-grained red beds extending into Kansas may have been derived, in part, from this source. Northward into Wyoming, the fan-shaped nature of the Fountain has been described by Knight (22) and its limits defined. The trough between the "Front Range" and "San Luis," in southern Colorado, received coarse sediments from both of those positive elements in upper Pennsylvanian and Permian times, which accumulated to a thickness of 11,000 feet or more. In the lower part of the Sangre de Cristo conglomerate, the coarseness of the pebbles appears to increase westward, indicating that the highest land existing at that time was on the northeastern shore of San Luis. Johnson (21, p. 9) mentions rounded fragments 3 or 4 feet in diameter and large angular or subangular pieces, which suggest material along or near the base of a sea cliff.

Beds equivalent to the Sangre de Cristo formation are found in New Mexico in the Abo and Yeso formations. The Abo is also of arkosic and conglomeratic nature, but contains no exceedingly coarse material as in the lower part of the Sangre de Cristo. It and the overlying Yeso were laid down at greater distances from the higher land areas and the equivalency of the Yeso to the upper part of the Sangre de Cristo is suggested by a large proportion of red shales in the latter on the Veta Pass road. In southern New Mexico the Abo thins and disappears, being evidently replaced by limestone. The red beds of the Yeso in southern New Mexico were deposited under marine conditions in a basin which was intermittently cut off from the open sea. The red shales and sandstones are interbedded with marine limestones and many thick layers of gypsum.

On the southwestern side of "San Luis," the Cutler formation was deposited. It corresponds in lithology and stratigraphic position with the Abo. Farther southwest the Supai occurs in Arizona and Utah as finer-grained red beds. The Maroon beds of central Colorado, a continuation of the Sangre de Cristo conglomerate, thin to 2,500 feet near Glenwood Springs and to 1,500 feet on White River, and disappear

entirely between that point and Juniper Mountain, the next outcrop of the Pennsylvanian northwest. The behavior of the red and maroon arkose and conglomerate here bears a close analogy to that of the Fountain in the Laramie Basin of southern Wyoming.

Deposition of light-colored sands from northwest.—The southeastern retreat of the shore line in Idaho and adjacent parts of Utah and Wyoming exposed to erosion a great area consisting largely of light-colored sands and quartzites of the older Pennsylvanian Weber, Wells, and Tensleep formations, while the areas of Algonkian quartzites farther northwest still remained. Throughout this territory, later rocks lie with marked erosional unconformity on the Pennsylvanian, of which the later portion is missing.

Deposition of light-colored sandstones continued in the northwestern part of the inland sea and they were distributed to greater distances from the original source. The resulting formations were the Weber of northeastern Utah and northwestern Colorado and the Tensleep of central and southern Wyoming.

Oscillations in this period, in Wyoming and northern Colorado, caused intermittent invasion of the sea separated by land conditions during which wind action was an important factor. The sands which alternate with marine limestones in the Ingleside formation are characterized by marked cross-bedding of the eolian type. The same is true of the Coconino of Utah and Arizona and the Glorieta of New Mexico, although here the marine limestones are lacking. Moreover, it is difficult to explain the spreading of this siliceous material over such a great area (Fig. 8) in any other manner than by wind action, inasmuch as a part of it, at least, seems to have been deposited in Arizona and New Mexico after the Park City and Phosphoria sea had been established in Wyoming and Idaho. In this basin marine shales and limestones were being laid down upon the homogenetic equivalents of the Coconino and Glorieta sandstones. The winds were prevailing from the west.

The spreading of these sands across the northern end of the Ancestral Rockies took place over areas where red beds had been previously deposited; thus, we find the light-colored sand mixed with red resulting in all shades from red to pink, the colors changing rapidly both laterally and vertically. In following the Ingleside southward, the "Front Range" shore line is approached at an angle and the number and thickness of the limestones decrease until at a point north of Lyons, Colorado, only a sandstone remains. In tracing this a short

distance farther south, the writer found stringers of typical Fountain arkose appearing in it and the Ingleside sandstone is eventually replaced by topmost Fountain beds. Northeastward the limestones of the Ingleside increase greatly in thickness, but upper sandstones persist and are recognizable in the upper Minnelusa of the Black Hills. It is not known to what distance they extend into Nebraska and South Dakota.

By late upper Pennsylvanian time the upward movement of the Ancestral Rockies had been retarded, the surface had been reduced to a lower elevation, and sedimentation had ceased, at least during temporary periods, except near the shore lines. The white sands from the northwest approached nearer the land areas of the Ancestral Rockies and were deposited over the red and maroon grits and arkoses whose source was in these eastern positive elements. On White River 90 feet of Weber sandstone overlies the Maroon formation and at Glenwood Springs the thickness is reduced to 25 feet.

The spread of these sands extended southward into Utah and Arizona as the Coconino and into New Mexico as the Glorieta. Noble (32, pp. 66-68) described the cross-bedding in the Coconino at Grand Canyon and classifies the sandstone as a dune deposit. The laminae of the cross-bedding are inclined at angles as high as "15 degrees to 25 degrees, or exceptionally 30 degrees" and "The prevailing dip of the laminae is south wherever the Coconino sandstone is exposed in northern Arizona."

In southeastern Utah and northeastern Arizona, the Coconino interfingers with the red beds of the Cutler, whose source was in the "San Luis" positive element in Colorado. This condition has been described by Baker and Reeside (1, p. 1443) who designate the principal "fingers" of the Coconino as the Cedar Mesa and De Chelly and the alternating red-bed members as the Halgaito, Organ Rock, and Hoskinini tongues. They are all included in the Cutler formation.

The Coconino was distributed in southern Arizona nearly to the border of the positive element in that locality. Its equivalent, the Glorieta sandstone, covered most of southern and central New Mexico, probably extending over the "Zuni" element.

The extension of the Glorieta into the Texas Panhandle is based on correlations by Gould and Willis (13), but it is believed that, although the beds designated as Glorieta may be the stratigraphic equivalent of the Glorieta of New Mexico, they may not necessarily have the same characteristics or have been derived from the same

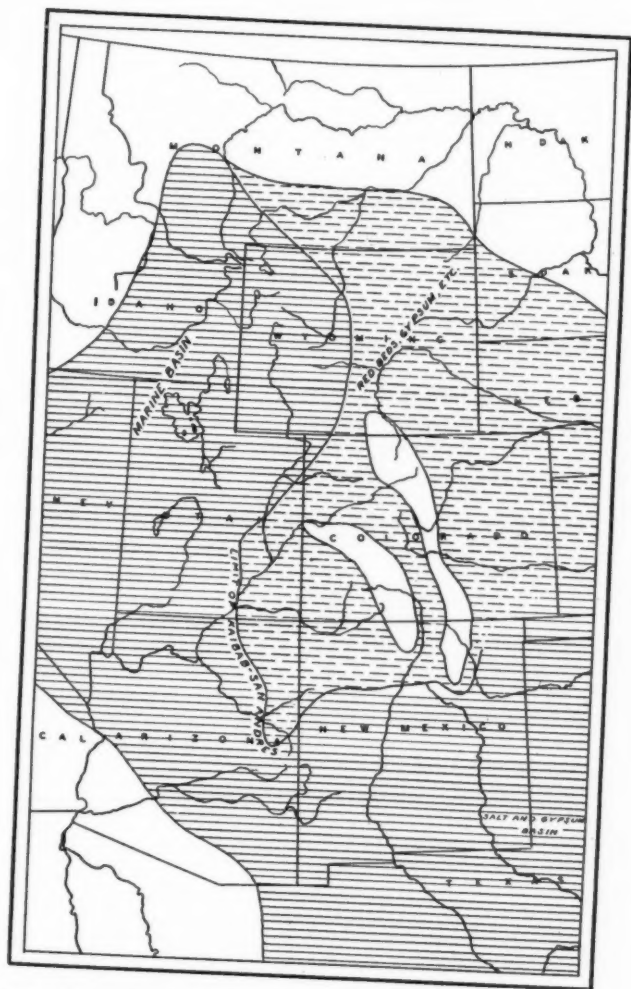


FIG. 9.—Paleogeography of Permo-Carboniferous and Permian: Lykins, Lyons, Forelle and Satanka, Minnekahta and Opeche, Embar, Park City, Phosphoria, Kaibab, San Andres, Castile, upper Naco, Gym.

source as the light-colored sands under discussion. The Duncan, which is given by Gould and Willis as the correlative farther east, probably had its source from the southeast.

PERMO-CARBONIFEROUS AND PERMIAN

The maps in Figures 8 and 9 are designed to show transgressive sedimentation processes which began in the northwestern part of the area and spread east, south, and southeast, involving sediments of similar lithology and like origin. Figure 8 therefore necessarily overlaps a period of geologic time the history of which was discussed under the heading "Late Pennsylvanian and Permo-Carboniferous."

Following the period of white sandstone deposition in the upper Pennsylvanian and before the end of that period, marine waters invaded from the west, being confined in the initial stages to a narrow arm across northern Nevada and Utah and covering a portion of southern Idaho and western Wyoming. The lower Park City and lower Embar formations were deposited on the eroded surface of the Weber, Tensleep, and Wells of those localities. The spread of the sea north and south continued apparently without interruption into Permian time, since the Phosphoria of Montana and Idaho and the upper Park City and upper Embar of Utah and Wyoming have been determined to be of Permian age.

Doubtless the distribution of eolian sands in Arizona and New Mexico still continued, while marine conditions prevailed in the northern territory.

The Permian sea spread southward, following closely the deposition of the Coconino sandstone. Marine conditions prevailed over much of Utah and Arizona in lower Kaibab time. Kaibab and Coconino deposition were closely associated, inasmuch as thinning of the Coconino westward was accompanied by a thickening of the Kaibab in the same direction. At Bass Trail, Arizona, and other localities, the Kaibab contains sandstone members.

During Phosphoria and upper Kaibab time the marine sea spread farther south and east and continued into New Mexico, where the San Andres limestone was deposited.

The zone of thickest limestone deposition in Kaibab-San Andres time lay nearly in the center of the basin between the Ancestral Rockies and the main western land area, that is, in northwestern Arizona. From there it extended southeastward into New Mexico and into the main Permian basin in the southeastern part of that state

and western Texas. The high area in southern Arizona remained essentially as in the preceding period.

The map (Fig. 9) shows the limits of deposition of the Kaibab and San Andres and their homogenetic equivalents. At no place did the limestones of the San Andres and Kaibab formations approach closely to the Ancestral Rockies, unless it can be said that they are represented along the eastern side of the "Front Range" by the "Crinkled limestone" member of the Lykins and the Forelle limestone of southern Wyoming.

The Ancestral Rockies maintained their state of relative quiescence and provided only fine-grained sediments, red in color. They were probably deposited for the most part in marine water, but not under continuous open-sea conditions as was the case farther west. The limestones have more the appearance of chemical precipitates and are associated with considerable amounts of gypsum. The lateral gradation from non-red marine sediments to red beds, thin limestones, and gypsum has been described by Condit (8). Corresponding strata in the Black Hills are the Opeche shale and the Minnekahta limestone, and in southern Wyoming, the Satanka shale and Forelle limestone. The Lyons sandstone, which occupies a limited area along the "Front Range" in Colorado, has been shown to change laterally, north and south, into the lower Lykins red beds. Its origin is in doubt, but its remarkable cross-bedding indicates a near-shore deposit and it is suggested that at this particular time a considerable area of pre-Cambrian quartzite may have been subjected to erosion in the land area at the west. Exposures of some of the quartzites show them to be associated with pre-Cambrian gneisses and schists. Examples are in the canyon of South Boulder Creek at Eldorado Springs, near the top of the range westward, and in the Big Thompson and Little Thompson canyons west of Loveland.

The Permian formations around the Ancestral Rockies are mostly red, due perhaps to the arid conditions under which the materials were eroded and transported. The Lyons sandstone is pink or cream-colored because very little iron was contained in the quartzites from which they were derived.

If the San Andres is considered as the approximate equivalent of the "Crinkled limestone" member of the Lykins, it follows that the portion of the Lykins below the "Crinkled limestone" must be the age equivalent of the Glorieta and a part of the upper Yeso of New Mexico. The Yeso may be equivalent to the upper Supai of Arizona, but it is

doubtful whether it has a counterpart in the Cutler of southwestern Colorado. Deposition may have taken place there in Yezo time, but since Upper Triassic beds lie on the Cutler, a period of erosion of sufficient duration to remove part of the Permian may have ensued during late Permian and Lower Triassic time. It is not known whether any deposits corresponding with the Park City are present in the Flat Top mountain district of northwestern Colorado, but at the base of the red beds, which are usually classed as Triassic in that territory, there is an alternation of gray sandy shales with the red beds which may be either of Permian or Lower Triassic age. If the latter, they would correspond with the Woodside and Thaynes formations of southwestern Wyoming.

The final retreat of the Permian sea was toward the south and southeast. Red beds younger than San Andres occur in eastern and southeastern parts of New Mexico and are designated as the Castile formation. Successively younger salt basins were in existence in Kansas, the Texas Panhandle, and southwest Texas as the sea withdrew.

LOWER TRIASSIC

The withdrawal of Permian marine waters was followed by a long period of erosion throughout all of the Rocky Mountain region which probably lasted from middle Permian into earliest Triassic time. Even after so long a lapse of time, the succeeding formations were laid down on the eroded surfaces of Permian beds with no appreciable angular unconformity.

In Lower Triassic time there began a slow oscillatory marine invasion from the west. In this basin the Moenkopi formation of Nevada, Utah, and Arizona was deposited. The lower part of the formation consists of sandstones, limestones, and gypsum with basal conglomerate as described by Longwell (27, p. 43) in southern Nevada and by Reeside and Bassler in southwestern Utah and northwestern Arizona (33, p. 59). This indicates a shallow sea near to a low land area which was probably on the south. As the sea spread eastward, true marine conditions prevailed in the western part of the area and limestones were the predominant sediments. In the eastern part the limestones are replaced by gypsiferous red shales and sands. The approximate maximum extent of the lower Triassic sea is shown in Figure 10; evidently it never reached the Ancestral Rockies. The surrounding land areas were evidently low and furnished only fine-grained detritus, limestone being deposited close to shore in some

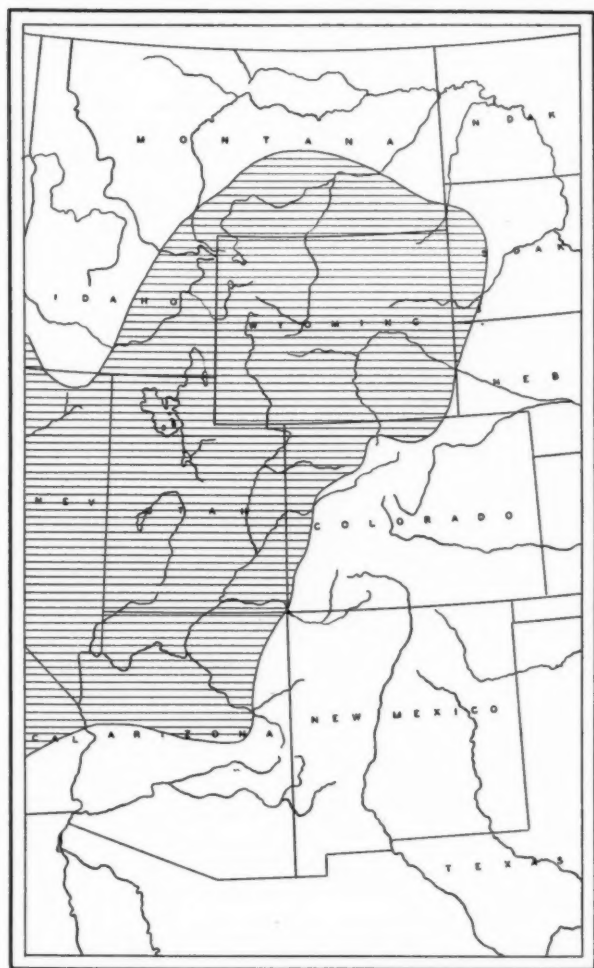


FIG. 10.—Paleogeography of Lower Triassic: Moenkopi, Woodside and Thaynes, Dinwoody, Chugwater, Spearfish, upper Lykins. Ruled area is basin of marine deposition.

places. The highest land was probably in southern Idaho, where a promontory extended southward into the basin. Around it the Lower Triassic formations are much thicker than elsewhere, aggregating 5,000 feet, of which 3,000 feet comprises the Thaynes group (30, pp. 87-90). The Thaynes is largely marine limestone corresponding with the same period of deposition as the marine beds of the Moenkopi in southern Nevada. The lower member of the Lower Triassic in southeastern Idaho is the Woodside shale, which has a maximum thickness of 2,000 feet near the ancient shore line. Beds equivalent to the Thaynes and Woodside have been recognized in northwestern Colorado, where there are no limestones and the total thickness of the shales and sandstones of the two formations does not exceed 800 feet. Similar beds in northern Wyoming which were formerly placed in the Embar formation have since been determined to be of Lower Triassic age and the name Dinwoody applied to them. In central and eastern Wyoming, Lower Triassic beds are included in the Chugwater formation.

The sea withdrew in the direction from which it came, oscillatory movements continuing, and leaving over the marine limestones additional red beds, gypsum, and sandstones similar to those deposited at the beginning of the period.

UPPER TRIASSIC

An interval of erosion followed the withdrawal of the Lower Triassic sea. The high area in southern Idaho extended through Nevada and probably connected with the positive element in southern Arizona (Fig. 11), cutting off westward marine connection between the Rocky Mountain region and the Pacific Ocean for all succeeding geologic time. The elevated area of Nevada and Idaho has been called the Nevada Continent by Lee (25), who applied the name more especially to its more extended development in Jurassic time.

The basal member of the Upper Triassic extending from Nevada to New Mexico and Utah is the Shinarump conglomerate, which is remarkably uniform in lithology in the entire area. It is doubtless of fluvial origin and is overlain conformably by the Chinle, which consists mostly of red beds. The latter formation thickens noticeably toward the "Nevada Mountains" and contains a greater proportion of sandstones, with shales. In the eastern part of the depositional basin there is also a thickening toward "San Luis," but excepting local occurrences of a basal conglomerate, the deposits comprising the Dolores formation are fine grained.

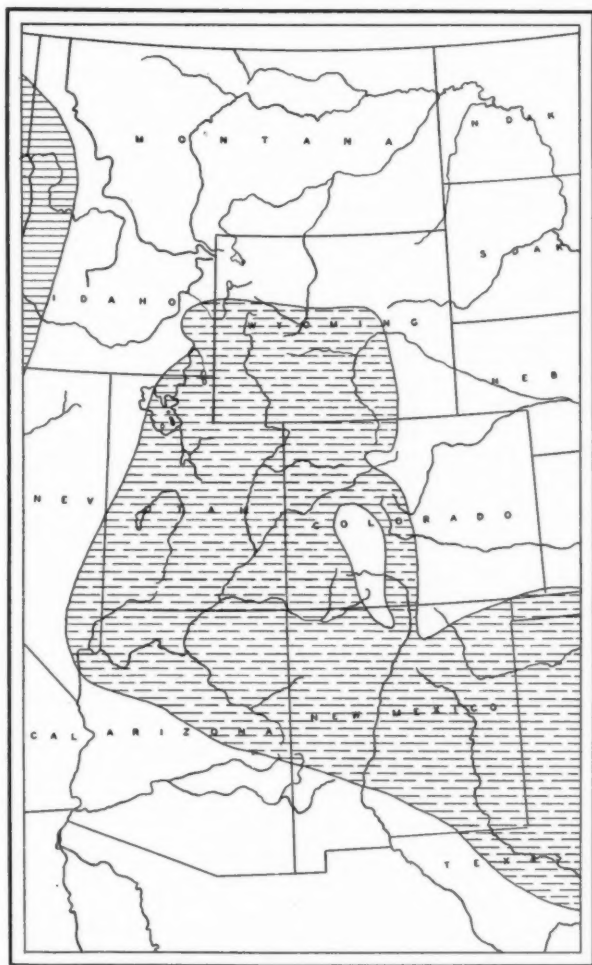


FIG. 11.—Paleogeography of Upper Triassic; Dockum and Santa Rosa, Shinarump and Chinle, Dolores, upper Wyoming, Ankareh, Jelm. Solid lines are marine deposits. Dashed lines are continental deposits.

The "San Luis" element did not extend so far northwest as in Permian time, but broadened eastward where Jurassic beds lie on the Pennsylvanian. The land area was low, approaching a peneplain.

It is doubtful whether any Triassic beds were deposited east of the "Front Range" except at the north end. If so, they were removed by early Jurassic erosion. In Wyoming the Upper Triassic is represented by the Jelm formation (Popo Agie) and by the Ankareh of the southwestern part and in Idaho. At the southeast the Dockum beds and the Santa Rosa sandstone were deposited in an arm of the basin which extended over eastern New Mexico and western Texas.

The red beds of the Upper Triassic and perhaps some of those belonging to the Lower Triassic and Permian periods were fluvial deposits. They do not necessarily indicate an arid climate because, as set forth by Dorsey (14), the color is the result of the dehydration of certain ferric oxide compounds, which takes place most rapidly in warm moist climates. The red ferruginous soils thus formed were redeposited on river deltas and flood plains and in lagoons. Marine limestones associated with red beds are due to temporary incursions of the sea.

Doubtless considerable percentages of the red beds are the result of a redeposition of earlier red beds. Red colors are also due in part to the red color of feldspars in arkosic beds near to granitic highlands. It seems to the writer that considerable areas of red beds deposited in association with salt and gypsum, as in the Permian basin of western Texas, were most certainly deposited in marine water and under arid climatic conditions. It may be that the concentrated salinity of the water precluded the presence of organic life in sufficient amounts to cause a reduction of the ferric to ferrous iron.

JURASSIC

Figure 12 is designed to show the probable extent of deposition in Glen Canyon time. The interpretation is based on the writer's conclusions as to the distribution of the Wingate, excluding it from northeastern New Mexico. It is possible that further data may change this interpretation, as explained on page 128.

The age of the Wingate and Kayenta is in doubt. They may belong anywhere in the Lower Jurassic or even as late as early Middle Jurassic. On the other hand, the relations of their correlative, the upper Dolores of southwestern Colorado, to the remainder of the Dolores is such as to indicate a possible Upper Triassic age for these

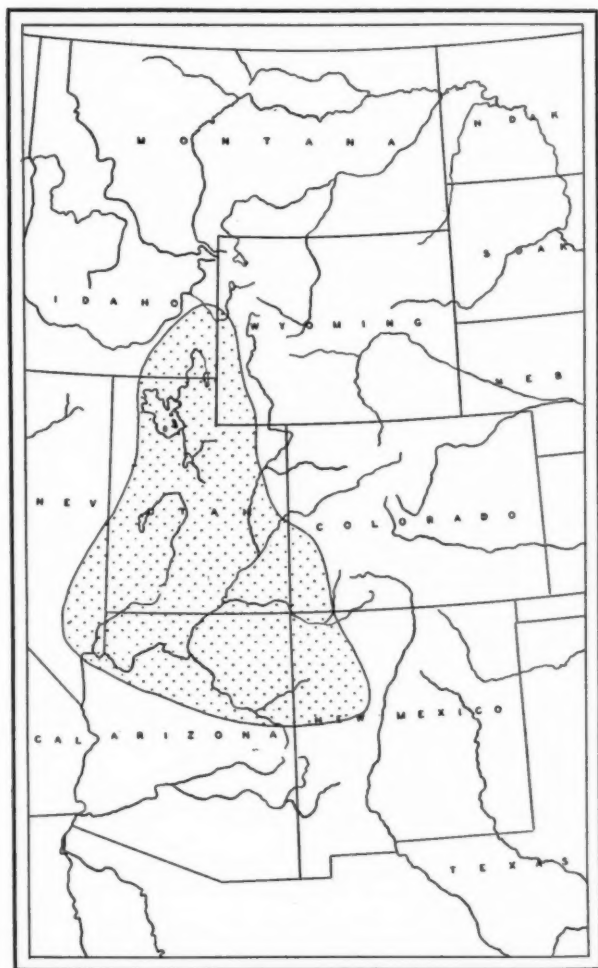


FIG. 12.—Paleogeography of Lower (?) and Middle Jurassic: Wingate, Kayenta and Navajo (Glen Canyon Group), Nugget. Dotted area indicates predominant eolian sediments.

beds. The Navajo is most likely Middle Jurassic. A separate map for Navajo time would show that it does not extend into New Mexico and only a short distance into western Colorado.

On the other hand, the Wingate and Kayenta equivalents probably do not extend far north of the San Rafael swell, and the type Nugget, the equivalent of the Navajo, occurs in southwestern Wyoming and southeastern Idaho.

It is believed that the Glen Canyon group is, for the most part, eolian in origin. Desert conditions existed over the depositional areas shown in Figure 11 for the greater part of the time, during which immense quantities of sand were distributed by wind action. The colors ranged from white to pink, salmon, and red. The materials were derived from all older formations exposed by erosion in preceding periods, but the greater proportion probably came as a result of the weathering of the great series of sands deposited in the area westward in Pennsylvanian time, namely, the Weber and its equivalents.

The thickest deposits are in the southwestern part of the basin. The "Nevada Mountains" at the west were of sufficient height to cause condensation of atmospheric moisture from the Pacific, leaving an exceedingly arid climate at the east. Limited stream flow down the eastern slopes of the mountains and occasional precipitation formed temporary playa lakes in which thin red shales and gray limestones were deposited. During the middle of the period, strata of this nature predominated and are given a formation name, Kayenta. The great thicknesses of predominantly eolian sands above and below the Kayenta are the Navajo and Wingate, respectively.

The history of the advance of marine Jurassic waters from the north into the Rocky Mountain geosyncline is a complex alternation of invasions and withdrawals which began in early Middle Jurassic time. In that epoch the sea extended southward in Canada almost to the Montana line, according to Crickmay (10, p. 84). His excellent series of maps show an emergence in late Middle Jurassic accompanied by vulcanism in California, western Canada, and Alaska.

The next invasion in early Upper Jurassic time extended to central Montana and the deposits of this and the earlier periods of sedimentation are included in the Ellis formation and the Fernie of Canada. An attempt has been made to show the approximate maximum extent of early Upper Jurassic waters in Figure 13. The deposits of this period are represented by the Ellis of Montana, the lower Twin Creek of southeastern Idaho, southwestern Wyoming, and

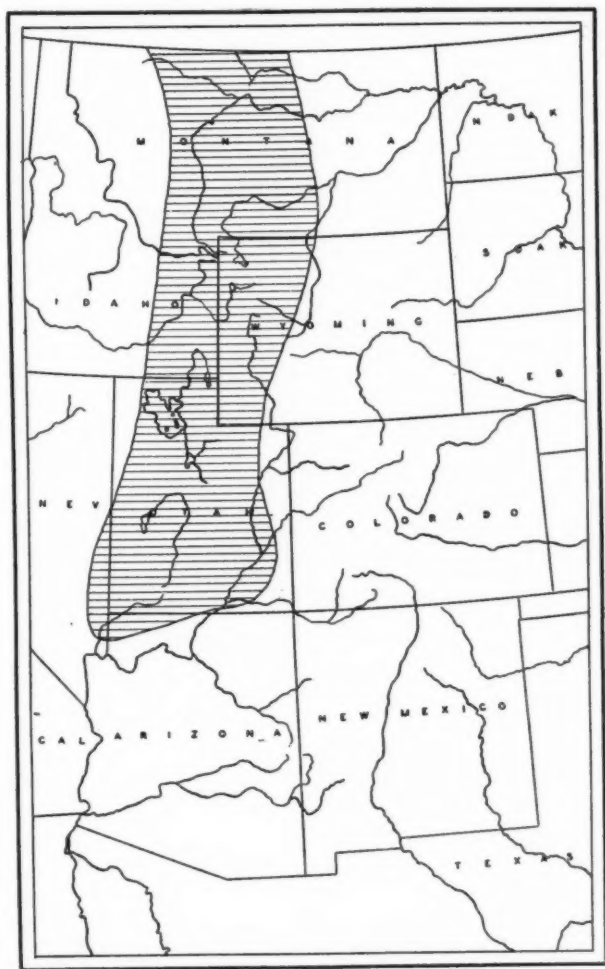


FIG. 13.—Paleogeography of early Upper Jurassic: Ellis, lower Twin Creek, and Carmel. Ruled area is basin of marine deposition.

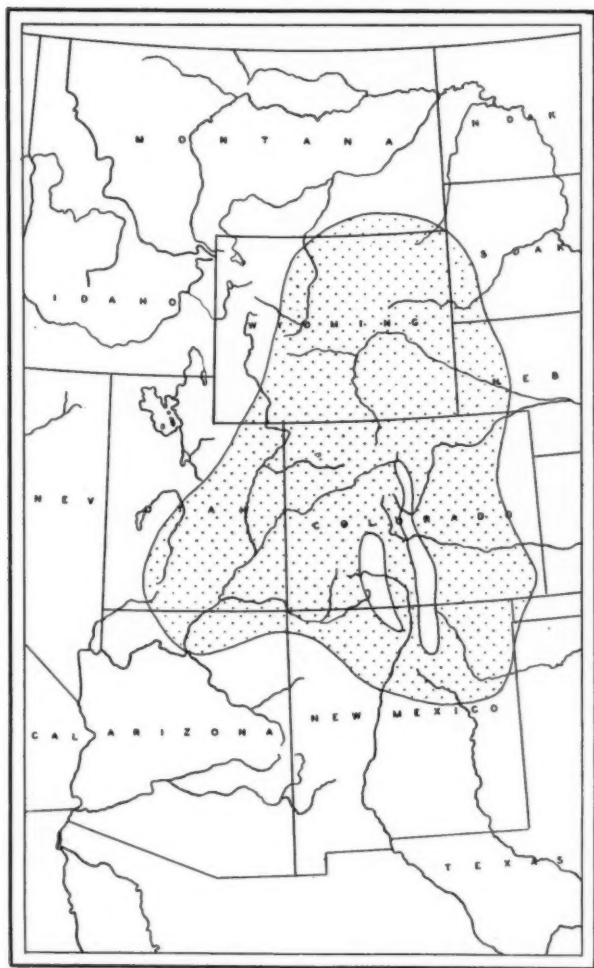


FIG. 14.—Paleogeography of middle (?) Upper Jurassic: Entrada, lower La Plata of Cross, basal Sundance Sand, Nugget (?), lower Morrison Sand of Front Range, Exter. Dotted area indicates predominant eolian sediments.

northern Utah and the Carmel of central and southern Utah. The Ellis formation overlies the Mississippian limestone in northern Montana and is in contact with successively younger beds toward the south.

The "Nevada Mountains" were high and the Ancestral Rockies were probably only a little higher than the general area around the marine basin.

The sea withdrew northward at least as far as Montana and there ensued a second period of desert conditions during which the major part of the sediments were of eolian origin. Light-colored sands predominated and spread over the area shown in Figure 14. They were thickest toward the west and doubtless originated in that direction.

The La Plata sandstone in southwestern Colorado overlaps all older beds from the Triassic to the pre-Cambrian rocks of "San Luis," but does not occur entirely over it. It is believed that dunes existed over most of "San Luis" as well as the "Front Range" periodically, but were eventually swept across them. Similar sands occur at the base of beds variously termed Morrison and Sundance all along the east side of the "Front Range" and are prominent in the northern part of Colorado beyond the northern end of the "Front Range" as it existed at that time. A few feet of sandstone with cross-bedding of the eolian type occur at the base of the Sundance in the Black Hills. In the Panhandle of Oklahoma the Exter sand can be seen to thin out and disappear, and near its easternmost extension it presents excellent examples of channel filling.

Another marine invasion from the north occurred in middle Upper Jurassic time, marking the widest extent of marine Jurassic sedimentation, as shown in Figure 15. In many localities it is noticeable that the upper few feet of the Entrada and its equivalents are evenly bedded. The supposition is that any irregularities on the surface of the dune sand were erased and the upper portion redeposited by the wave action of the encroaching marine waters.

The Ancestral Rockies were essentially as in preceding periods of the Middle and Upper Jurassic. The region around them was only slightly higher than the area westward, wherein lay the main marine basin. The "Nevada Mountains" were still effective, the thickness of the clastic sediments increasing toward the west. The final withdrawal of the sea was in the direction from which it came, leaving successively younger beds in that direction. Considerable quantities of light-colored sands are contained in the upper Ellis of southwestern

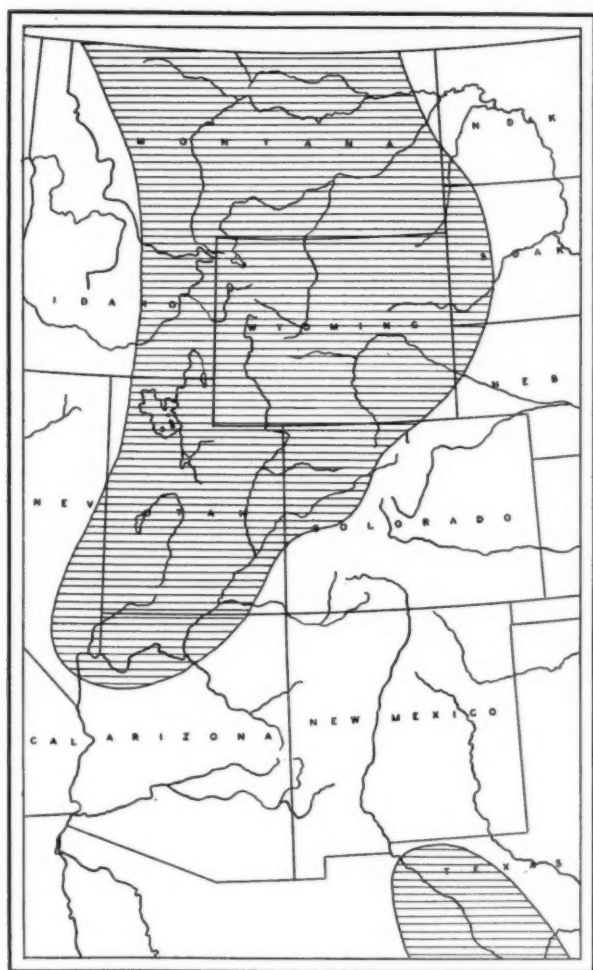


FIG. 15.—Paleogeography of middle Upper Jurassic: Curtis, Summerville, Sundance, Ellis (in part), upper Twin Creek. Ruled areas are basins of marine deposition.

Montana and the occurrence of the Pruess and Stump sandstones of southeastern Idaho may represent this period of withdrawal, although it is possible the Stump, at least, indicates a still later marine invasion. The Fernie formation of Canada contains both earlier and later marine beds than any south of the international boundary.

According to Crickmay (10, p. 90), the withdrawal of the Sundance sea was accomplished before the end of middle Upper Jurassic. The west coast was submerged as far east as western Nevada, and a Mexican arm of the sea encroached nearly to the southern boundary of New Mexico. In late Upper Jurassic (10, p. 91) little of the west coast remained submerged, while the Mexican sea had withdrawn to the big bend of the Rio Grande. The writer believes that during these two epochs, continental sedimentation was taking place in the Rocky Mountain region since the earlier stages, as represented by the limestone and gypsum of the Todilto and lower Morrison, appear to have close relationships to the underlying Sundance beds. The map (Fig. 16) shows the approximate areas covered by continental deposits of this period.

Evidently a warm moist climate prevailed and the region was covered by fresh-water lakes and swamps in which were deposited variegated marls, shales, limestones, and sandstones of the Morrison formation. The greater part of the coarser clastic sediments was still coming from the "Nevada Mountains" and the formations are thickest in the western part of the area. Many massive sandstones occur in the lower part of the McElmo of western Colorado and Utah, the Beckwith of southwestern Wyoming, and the Zuni of western New Mexico. The upper McElmo is very similar in lithology to the Morrison of eastern Colorado.

The Ancestral Rockies still existed as very low positive elements, the size of "San Luis" having been considerably decreased from that of Middle Jurassic time.

CRETACEOUS

The drying-up of the Morrison lake was followed by dry land conditions in the Rocky Mountain region throughout the early part of Lower Cretaceous time, assuming that the Morrison is confined entirely to the Jurassic. During this period the base-leveling of the Ancestral Rockies was completed. They had been very low and near base level for a long period of time, and this condition may have caused the descent of the isogeotherms and a resultant thermal contraction. The subsequent sinking initiated the great marine invasion

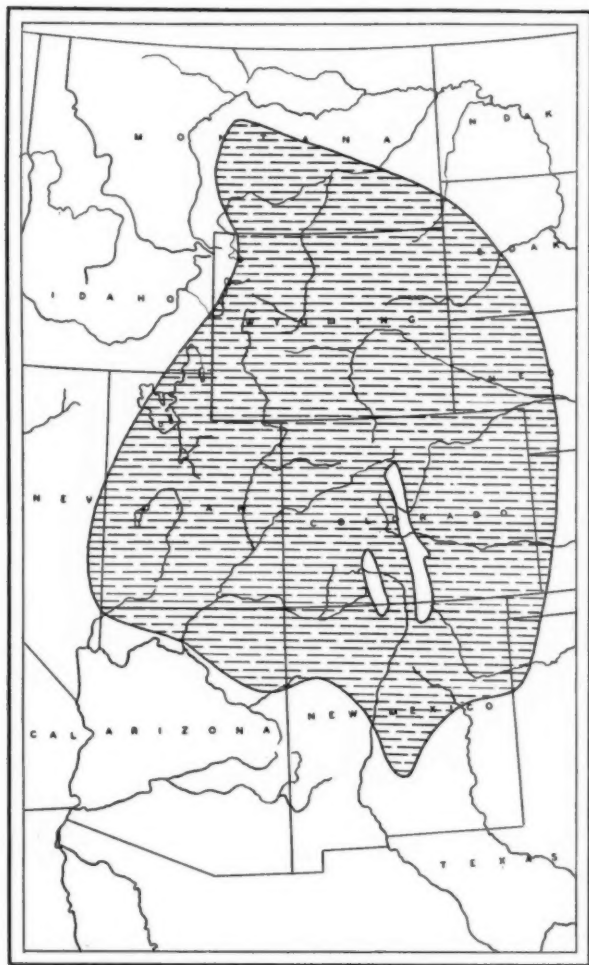


FIG. 16.—Paleogeography of late Upper Jurassic: Morrison, McElmo, Todilto, Zuni, upper Beckwith. Dashed lines show continental deposits.

from the Arctic Ocean and the Gulf of Mexico which was destined to develop into the most widespread epi-continental sea in the history of the region.

Lower Cretaceous history.—No attempt has been made to work out the details of Lower Cretaceous history. The approximate distribution of Lower Cretaceous sediments is shown in Figure 17. Early Lower Cretaceous formations of the Rocky Mountain region are predominant continental deposits and are perhaps represented in southern Colorado by a portion of the lower sandstones of the "Dakota group." Northward they thicken and contain colored shales alternating with two or more prominent sandstones, as represented by the Fuson and Lakota of the Black Hills, the Cloverly of Wyoming, and the Kootenai of Montana.

Conditions of deposition were evidently little different from those in the Morrison epoch. Marine invasion from the north probably did not reach south of the Canadian border.

In Washita time, Gulf marine waters had covered western Texas, eastern New Mexico, and eastern and north-central Colorado, and perhaps spread a considerable distance farther north. The Washita formations are the Purgatoire of southern Colorado and the upper shale member of the "Dakota group" of northern Colorado and the underlying or "middle sandstone member" (24, p. 20). Washita deposition is represented in the Black Hills by the Skull Creek shale and the Fall River sandstone and in western Kansas by the Kiowa shale and the Cheyenne sandstone.

It is not known how far west the Comanche strata occur, although a Fuson flora is reported from the coal-bearing horizon of the "Dakota group" in western Colorado.¹ There were probably two or more small areas in the region of the Ancestral Rockies of Colorado on which no Lower Cretaceous beds were deposited (Fig. 17). It is possible also that the upper sandstone of the "Dakota group," which is considered of Upper Cretaceous age, was absent or very thin at these localities (28, p. 88).

Upper Cretaceous history.—The Upper Cretaceous map (Fig. 18) is greatly generalized and is designed to show the widest extent of the Upper Cretaceous sea together with the general distribution of predominant continental deposits as compared with those which are mostly of marine origin. It also indicates that Upper Cretaceous formations, with the possible exception of the upper sandstone of the

¹ J. B. Reeside, Jr., personal communication.

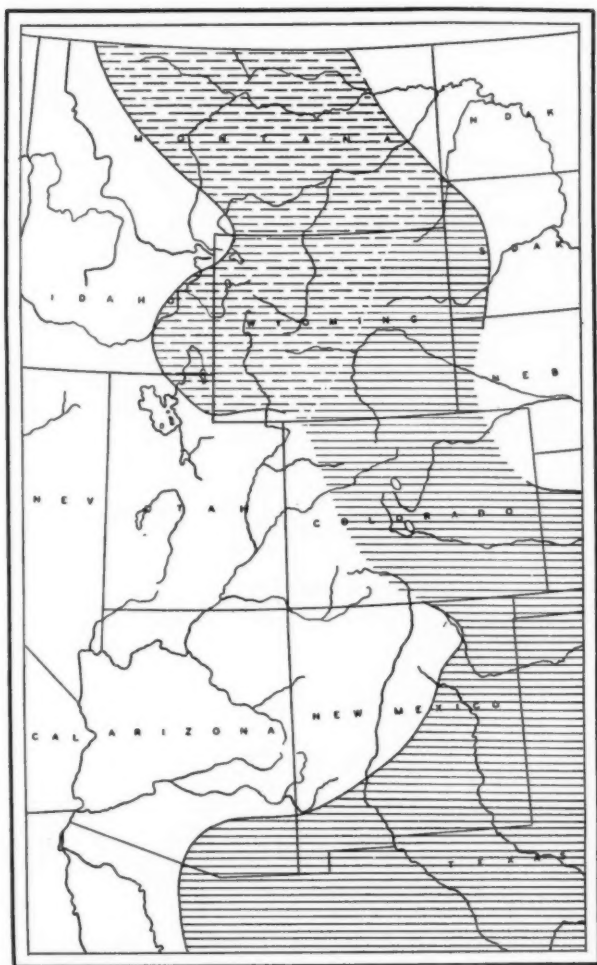


FIG. 17.—Paleogeography of Lower Cretaceous: Purgatoire, Fuson, Lakota, Cloverly, Kootenai. Solid lines are predominant marine deposits. Dashed lines are predominant continental deposits.

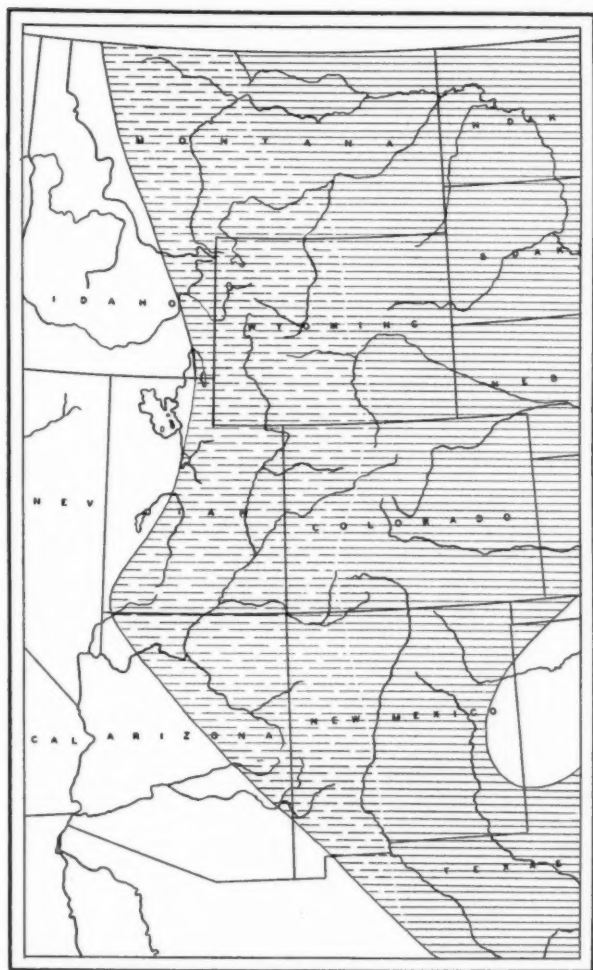


FIG. 18.—Paleogeography of Upper Cretaceous: "Dakota," Benton, Niobrara, Pierre, Fox Hills, and their equivalents. Solid lines are predominant marine deposits. Dashed lines are predominant continental deposits.

"Dakota group," extend continuously across the site of the Ancestral Rockies, which had now become a part of the Rocky Mountain geosyncline.

Spreading of marine waters east and west, with the accompanying deposition of basal sandstones, continued from Lower Cretaceous into Upper Cretaceous time, although the exact extent of the sea at the end of Lower Cretaceous time is unknown. The lower members far toward the west may be of Comanche age. The widest extent of the sea was attained in early Benton time.

Upper Cretaceous formations were deposited up to thicknesses of 14,000 feet and inasmuch as none of these was in deep water, there must have been a continuous sinking. The zone of thickest sediments extends east of south from western Montana through southwestern Wyoming, the point of maximum thickness, to northwestern New Mexico (15, p. 5). The source of the major portion of the sediments was evidently at the west, where the "Nevada Mountains" were still prominent. Generally speaking, all of the Cretaceous formations become more sandy along the western margin of the epicontinental sea. At intervals a shoaling of the sea bottom occurred, resulting in the spreading of sandy material eastward, and as a natural result the sandstones thin in the same direction. Examples are the Frontier and Carlile horizons and the Mesaverde formation. Halting upward movement which finally resulted in the draining of marine waters from the Rocky Mountain region may have begun as far back as middle Pierre time or earlier. Marine deposition ended with the Fox Hills sandstone series in eastern Colorado, but continental deposits of late Montana age were being laid down in other districts. Post-Montana formations were continental deposits and were confined to separate basins for the most part. The same was true of later beds such as the Denver and Arapahoe formations and their equivalents, which mark the transition from Mesozoic to Cenozoic time.

CENOZOIC

Laramide revolution.—The present Rocky Mountains are the result of at least four upward movements in Tertiary and Quaternary time, separated by periods of erosion in which mature topography was developed (28, p. 95). This indicates that the maximum elevation of the Rocky Mountains was developed in early Tertiary time and that the present period represents a stage in their history during which they are still being elevated, but that denudation is faster than uplift.

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VOSHELL FIELD, MCPHERSON COUNTY, KANSAS¹

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ABSTRACT

The Voshell field is described herein, beginning with its discovery in August, 1929, and ending with its second anniversary. The stratigraphy indicates that folding and faulting occurred chiefly in the pre-Marmaton, post-"Mississippi lime" time interval. Commercial production is found in three limestone and two sandstone formations. Oil and gas occur coincidentally with the anticlinal folding, with saturation co-extensive with measurable limits of closure. Water movement is from east to west in adjustment to volumetric replacement of oil withdrawals and appears to be the chief propulsive agent. Proration was enforced a year, ending February, 1931. On October 1, 1931, the field had produced 8,413 barrels per acre, with 10-acre spacing, from 104 wells, the daily average production being 135 barrels per well.

INTRODUCTION

Location.—The Voshell field, named after the discovery tract, extends from Sec. 27, T. 20 S., R. 3 W., to Sec. 16, T. 21 S., R. 3 W., McPherson County, Kansas, and is remarkably narrow. Figure 1 depicts the geographic relation of the field to surrounding development.

History of development.—The discovery well in the field, Washabaugh *et al.* Voshell No. 1, northeast corner, Sec. 9, was completed in August, 1929, with a depth of 3,303 feet. Due to the poor mechanical condition of the hole, the top of the Simpson group was barely penetrated, resulting in an initial production of only 25 barrels.

The discovery well drilled to the "Wilcox sand," the Derby Oil Company's Stucky No. 1, NE. $\frac{1}{4}$, SE. $\frac{1}{4}$, Sec. 9, was completed in October, 1929, with an initial production of 2,180 barrels, at a depth of 3,333 feet.

The discovery well drilled to the Arbuckle limestone, the Indian Territory Illuminating Oil Company's Voshell No. 2, SE. $\frac{1}{4}$, NE. $\frac{1}{4}$, NW. $\frac{1}{4}$, Sec. 9, was completed in March, 1930, with an initial production of 889 barrels, at a depth of 3,483 feet.

The major development of the field occurred prior to the end of May, 1930, when 70 wells had been completed, and the eastern and

¹ Manuscript received, July 12, 1932.

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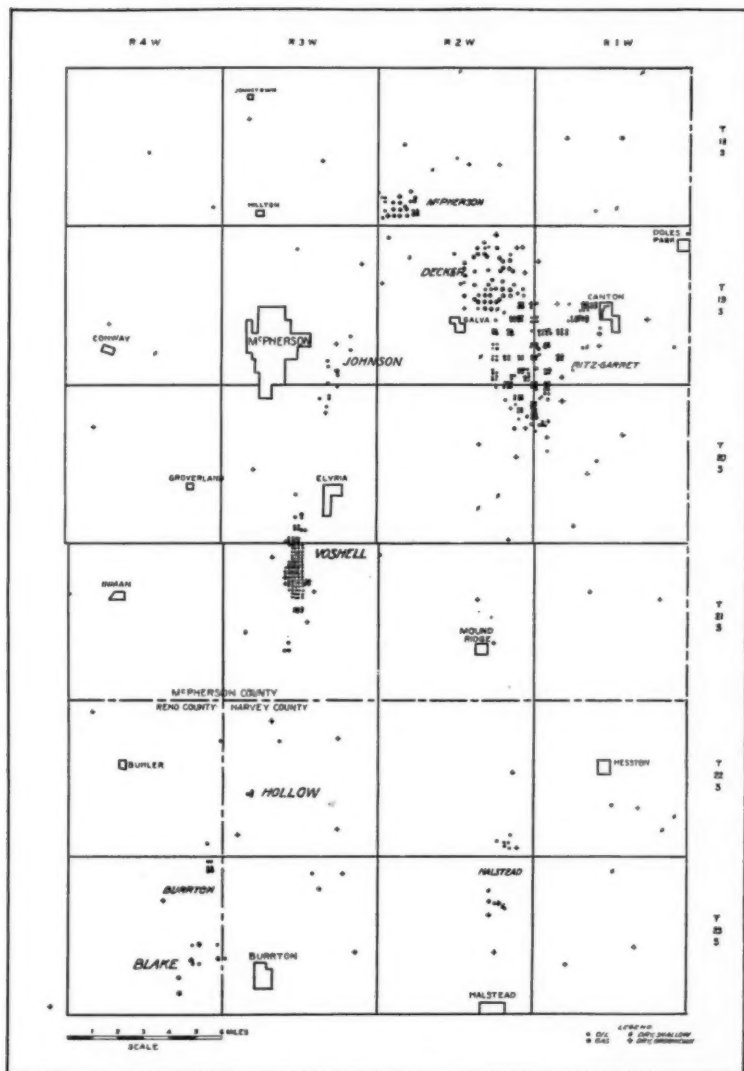


FIG. 1.—Index map, to show Voshell field and near-by oil and gas fields, revised to June, 1932.

western sides were defined. At the end of January, 1931, there were 95 wells; at the end of September, 1931, 104 wells.

Scope of article.—The account of the field is treated under three phases: geology, drilling practice, and production methods. The description is intended mainly to qualify interpretations expressed by the illustrations.

Acknowledgments.—The data have been compiled through the coöperation of the employees of W. C. McBride, Inc., and of various other operating companies.

GEOLOGY

Topography.—The Voshell field and environs possess extreme topographic flatness. Drainage channels provide neither adequate supply for many simultaneous operations nor sufficient means of preventing flooding in rainy seasons. The soil varies from thick, black muck to loam. No rocks crop out in the locality.

SUBSURFACE STRATIGRAPHY

Quaternary.—Figure 2 illustrates the stratigraphy. The McPherson formation comprises unconsolidated gravel and sand.

Permian and Pennsylvanian.—The classification of these sediments is arranged after the recent work of Condra and Upp,¹ Bass,² and Moore.³

For utility in subsurface studies the writer favors the proposal of Bass to include the strata between the "Red-beds" and the top of the Winfield limestone in the Sumner group. The Chase-Council Grove groups are conveniently unitized. The lower boundary of the Council Grove is taken as the base of the Americus limestone after Moore, and this is also the base of the Big Blue series and of the Permian (?). The base of the Permian (?) is more or less arbitrarily established by Moore, although in subsurface studies the boundary is a natural one and is adopted here accordingly.

The groups and series in the Pennsylvanian are arranged after Moore, with the Wabaunsee-Shawnee contact at the top of the Topeka limestone, and the Shawnee-Douglas contact at the base of

¹ G. E. Condra and J. E. Upp, "Correlation of the Big Blue Series in Nebraska," *Nebraska Geol. Survey Bull.* 6, 2d ser. (1931).

² N. W. Bass, "The Geology of Cowley County, Kansas," *State Geol. Survey of Kansas Bull.* 12 (1929).

³ R. C. Moore, "A Reclassification of the Pennsylvanian System in the Northern Mid-Continent Region," *Kansas Geol. Soc. Sixth Ann. Field Conference Guide Book* (1932.)

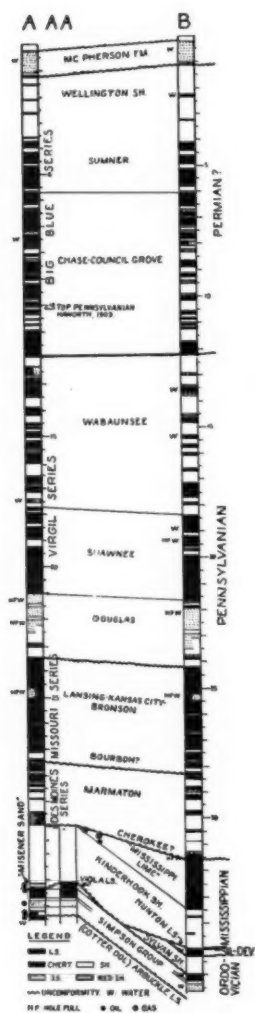


FIG. 2.—Type logs, Voshell field. Log AA is typical for wells on anticline at north end of field. Log A is typical for wells on anticline in central part of field. Log B is typical for areas adjacent to anticline. Scale shown in hundreds of feet.

the Oread limestone. The Douglas-Lansing contact marks the base of the Virgil series, and the top of the Missouri series. The unconformity is best recognized in regional cross sections, but appears to account for some loss of section local to the Voshell field.

The Missouri series is not subdivided, but includes in the Voshell field representatives of the Lansing, Kansas City, Bronson, and possibly Bourbon groups. The Des Moines series is likewise not subdivided, and includes Marmaton with an uncertain representation of Cherokee sediments. The chert conglomerate at the base of the Pennsylvanian can be differentiated from the "Mississippi lime" in many, but not all, wells.

Mississippian.—The field-term, "chat," is used to include either the chert conglomerate or the upper part of the "Mississippi lime," or both, in a given well. The thickness of the "Mississippi lime" is extremely variable due to truncation subsequent to anticlinal folding. Leaching and silicification appear to be especially characteristic in the upper 50 feet of the section present.

The "Mississippi lime"-Kinderhook shale contact is generally distinct, with no angular unconformity found in the Voshell field. However, the thickness of the Kinderhook shale is also variable. This condition is regarded as due to deposition over an irregular pre-Mississippian floor.

At or near the base of the Kinderhook shale, a lenticular sandstone member is found in several wells, which has been called "Misener sand" in the field. It is considered approximately correlative with the "Misener sand," Sylamore sandstone, of Oklahoma.

*Silurian and Devonian.*¹—In Figure 2, log B, the dolomitic limestone underlying the Kinderhook shale is correlated with the Hunton limestone, in recognition of the paleontological evidence of its Siluro-Devonian age cited by McClellan,² and the confirmation of such age by H. S. McQueen.³ The name, Hunton, is adopted from the nomen-

¹ The Kinderhook shale and pre-Mississippian rocks in Kansas have been described by Barwick, Edson, and McClellan.

John S. Barwick, "The Salina Basin of North-Central Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12, No. 2 (February, 1928), pp. 177-99.

Fanny C. Edson, "Pre-Mississippian Sediments in Central Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, No. 5 (May, 1929), pp. 441-58.

Hugh W. McClellan, "Subsurface Distribution of pre-Mississippian Rocks of Kansas and Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 12 (December, 1930), pp. 1535-56.

² *Op. cit.*

³ Personal communication, regarding studies of insoluble residues.

clature of Oklahoma formations, since this is the only available stratigraphic term for Siluro-Devonian rocks in states surrounding Kansas. The Hunton in the vicinity of the Voshell field has not been subdivided into individual members.

Ordovician.—The gray, dolomitic shale which underlies the Hunton limestone is correlated with the Sylvan shale. The observations of McQueen¹ are in agreement as to its correlation with the Maquoketa shale of Missouri, an equivalent of the Sylvan. Harlton² has identified graptolites from rotary cores in the Stanolind Oil and Gas Company *et al.* Zenger No. 1, NW. $\frac{1}{4}$, NE. $\frac{1}{4}$, SE. $\frac{1}{4}$, Sec. 16, correlating the shale below the Kinderhook with the Sylvan as illustrated in Figure 6, right side of cross section.

In wells in the northern end of the field, for example, Slick's Gratton No. 2, SW. $\frac{1}{4}$, NW. $\frac{1}{4}$, Sec. 34, a dolomitic limestone containing a characteristic gray, speckled chert, is found underlying the Kinderhook shale, as illustrated in Figure 2, log AA, and is correlated with the Viola limestone. This formation is considered to be correlative with the Maysville-Eden groups of the Galena described by Edson³ and the Viola limestone described by Decker.⁴

In the general territory including and surrounding the Voshell field a persistent, white-to-gray, coarsely crystalline, dolomitic limestone occurs, which may be found to underlie the Kinderhook shale, the Sylvan shale, or the Viola limestone. This limestone formation, included in the Simpson group (Fig. 2) is considered a correlative of the Prosser formation as described by Edson⁵ and Decker.⁶ The term Urschel was used by Barwick⁷ to include the limestone section occupied by both the Viola and Simpson limestones as used herein. The top of the Simpson limestone is generally used as the datum horizon for subsurface structural mapping in central Kansas.

The name Simpson group was proposed by Decker⁴ in place of Simpson formation, and is used herein to include members A to H,

¹ Personal communication, regarding studies of insoluble residues.

² B. H. Harlton, personal communication.

³ *Op. cit.*

⁴ Charles E. Decker, "Simpson Group of Arbuckle and Wichita Mountains, Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 12 (December, 1930), pp. 1493-1505, Table VI.

⁵ *Op. cit.*

⁶ *Op. cit.*, also Charles E. Decker and C. A. Merritt, "The Stratigraphy and Physical Character of the Simpson Group," *Oklahoma Geol. Survey Bull.* 55 (1931).

⁷ *Op. cit.*

illustrated in Figure 3. With the exception of the limestone, member *H*, in the Simpson group, it is considered questionable whether the members can be traced any distance away from the Voshell field. Possibly members *A* to *E*, inclusive, constitute a zone which persists into Oklahoma and is correlated with the Tyner shale.¹

In field terms the upper limestone of the Simpson beds has been called "Viola limestone" and member *F* (Fig. 3) has been called "Wilcox sand."

The cherty, oölitic dolomite under the Simpson group (Fig. 3) is correlated with upper Arbuckle limestone, more particularly the Cotter dolomite, in agreement with the observations of McQueen.²

In well cuttings and cores, the evidences of leaching have been observed in the upper portions of the "Mississippi lime," the Simpson limestone, and the Cotter dolomite. And associated with leaching, it seems logical to consider that the bedding and joint planes have been enlarged by solution. Possibly additional jointing has resulted from the anticlinal folding.

STRUCTURE

Foreword.—No surface structural mapping is possible in the vicinity of the Voshell field. Core drilling was used extensively in the territory for mapping the structure on the limestone formations in the Sumner group. The cross sections (Figs. 5 and 6) present interpretations from well logs of the structure on the various formations from the surface to the Arbuckle limestone. The profiles indicate that data on shallow formations will assist in localizing the area of pre-Pennsylvanian structure. In Figure 5, the exaggeration of the vertical scale obscures a slight westward shifting of the axis progressive with depth, which the writer observed.

Pre-Pennsylvanian regional structure.—The area mapped in Figure 1 contains regional monoclinical south-of-west dip. A few miles west of the area mapped, the regional syncline is located, which divides the west dip away from the Ozark uplift from the east dip away from the central Kansas uplift.

The McPherson, Johnson, Voshell, Hollow, Burrton, and Blake oil and gas fields appear to be on an anticlinal trend, in which the folding is chiefly pre-Pennsylvanian. This trend is somewhat in contrast to the Decker and Ritz-Garret field where the folding is less in-

¹ The name Tyner shale is used as illustrated in the well log (Fig. 8), by Luther H. White, in *Oklahoma Geol. Survey Bull.* 40-C (1926), p. 42.

² *Op. cit.*

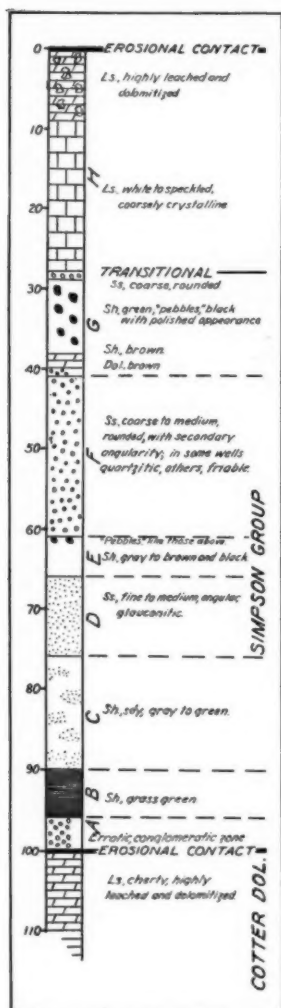


FIG. 3.—Detailed stratigraphic section, Simpson group, Voshell field. Scale shown in feet.

tense, particularly in pre-Pennsylvanian sediments. The trend through the Voshell field may eventually be traced into the Abilene anticline, which is mappable northward from Abilene, T. 13 S., R. 2 E., Dickinson County.¹

Subsurface, local structure.—Figures 5 and 6 illustrate the folding and faulting in cross section along the major and minor axes. Figure 4,

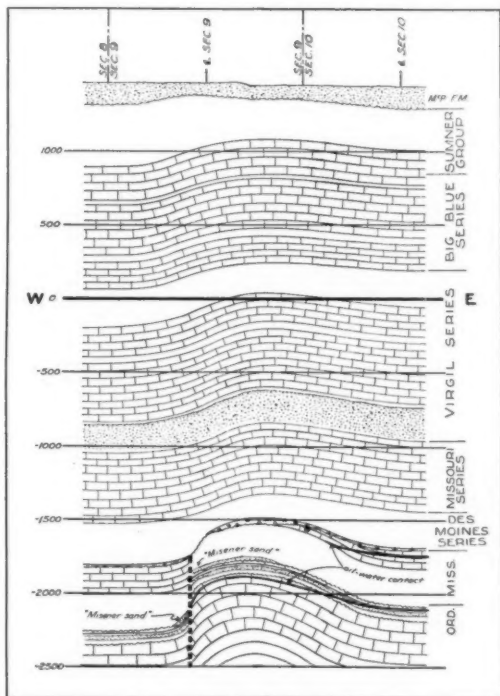


FIG. 5.—Cross section, west to east, Voshell field. For plan refer to Figure 4. This cross section also applicable to conditions in Sections 33 and 34. Vertical scale in feet.

¹ In personal communication, S. K. Clark states that he interprets these "granite-ridge" type anticlinal trends as being related to shear lines in the Basement complex which have resulted from north-south adjustments in the earth's crust.

The writer has observed some evidence of pre-Mississippian cross-graining, with low axes arranged northwest-to-southeast in trend. The studies have not been in progress throughout wide areas, but suggest that the warping is chiefly pre-Sylvan in age near the Voshell field.

a map of the field contoured on the top of the Simpson limestone, is considered to depict the structure coincident with the occurrence of oil and water in the Simpson group and Arbuckle limestone. The contours were drawn freely, since tests revealed that several holes deviated from the vertical and possibly drifted laterally to some extent. The interval of 50 feet was used to avoid minor irregularities and errors. In mapping the fault trend on the western side of the field, the

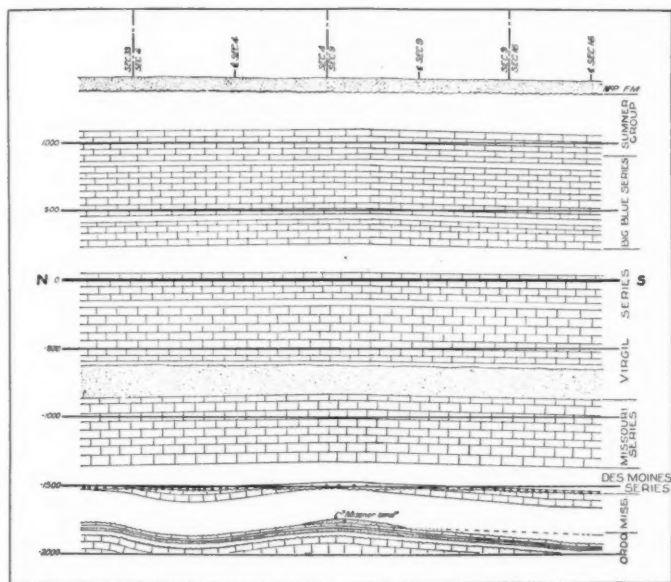


FIG. 6.—Cross section, north to south, Voshell field. For plan refer to Figure 4. Vertical scale in feet.

interpretation of stratigraphic evidence was used rather than the criterion of steep dip.¹

¹ In constructing the profile (Fig. 5), the following observations were considered significant: the thick "Mississippi lime" section of wells adjacent to the anticline was present in the Gypsy Oil Company's Stucky No. 1, SW. $\frac{1}{4}$, SW. $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 33, while at one location west, in the Gypsy's Stucky No. 1, SE. $\frac{1}{4}$, SW. $\frac{1}{4}$, SE. $\frac{1}{4}$, Pennsylvanian shale rested on Kinderhook shale; in the Gypsy's K. Stucky No. 1, SE. $\frac{1}{4}$, SE. $\frac{1}{4}$, SW. $\frac{1}{4}$, Sec. 9, the Simpson limestone was encountered overlying shale of post-Simpson age (?) which in turn was found to overlie the Simpson group sediments and Arbuckle limestone in normal sequence; beneath a normal section of Kinderhook shale and Simpson limestone, the members G to A of the Simpson group showed excessive thicknesses in the I. T. I. O. Voshell No. 1, NE. $\frac{1}{4}$, NE. $\frac{1}{4}$, NW. $\frac{1}{4}$, Sec. 9; in the Stanolind-Amerada's

The development to date suggests that the fault trend is approximately north-south, comprising short *en échelon* faults and cross-fracturing. The angles of dip of the faults are estimated to be approximately vertical.

As shown in Figure 4, no control is available to afford measurement of the critical north-closing dip at the north end of the field. The superimposed domes in Secs. 33 and 9, as interpreted in Figure 6, are chiefly pre-Marmaton in age. Other similar domes may be found with drilling north or south of the present limits of development.

COMMERCIAL RESERVOIR HORIZONS

The "chat" is non-productive in Secs. 4, 9, 33, and 34, within the areas bounded by the -1,800-foot contour (Fig. 4), which is considered to be due to the fact that it consists only of the Pennsylvanian conglomerate. In the saddle, Section 4, and along the eastern and southern parts of the field, virtually all the wells have encountered gas or fluid, or both, in the "chat," in which areas both Pennsylvanian conglomerate and "Mississippi lime" are present. In these areas the "chat" yields its maximum production at a penetration of approximately 55 feet. The maximum oil production was slightly more than 500 barrels. The maximum gas production was approximately 30,000,000 cubic feet, with 1,000 pounds rock pressure. Wells adjacent to the anticline encountered water in the "chat." Figure 7 designates wells which had showings or commercial production from the "chat."

The "Misener sand" production is likewise designated in Figure 7. The distribution of the sand lens is mainly in the NE. $\frac{1}{4}$, Sec. 9. The average thickness is slightly less than 20 feet. The sand grains are very similar to the "Wilcox sand." The maximum production was 40 barrels per hour in a 3-hour swabbing test.

The upper 7 feet of the Simpson limestone was observed to be porous throughout the field. However, the common practice was to complete a well in the "Wilcox sand" before testing. The average

Voshell No. 1, NE. $\frac{1}{4}$, SE. $\frac{1}{4}$, NW. $\frac{1}{4}$, Sec. 9, the Kinderhook shale thickness was normal, but the Simpson limestone was approximately four times normal thickness; cores in member G, Simpson group, showed evidence of squeeze or flowage with the distorted bedding planes in vertical position, and this member was also excessively thick; and in the Independent's Sperling No. 1, NE. $\frac{1}{4}$, NE. $\frac{1}{4}$, SW. $\frac{1}{4}$, Sec. 9, the "chat" and Kinderhook shale thicknesses were normal, but the "Misener sand" was excessively thick, and whereas the interval from the "Misener sand" to the top of the Simpson limestone is less than 25 feet in near-by locations, the well encountered an interval of more than 200 feet to the Simpson limestone, and the Simpson limestone was abnormally thin. Though these irregularities are not cited to prove faulting, the fact that the thicknesses become greater or less than normal so erratically is considered to indicate a complex zone combining steep dip and fracturing or faulting.

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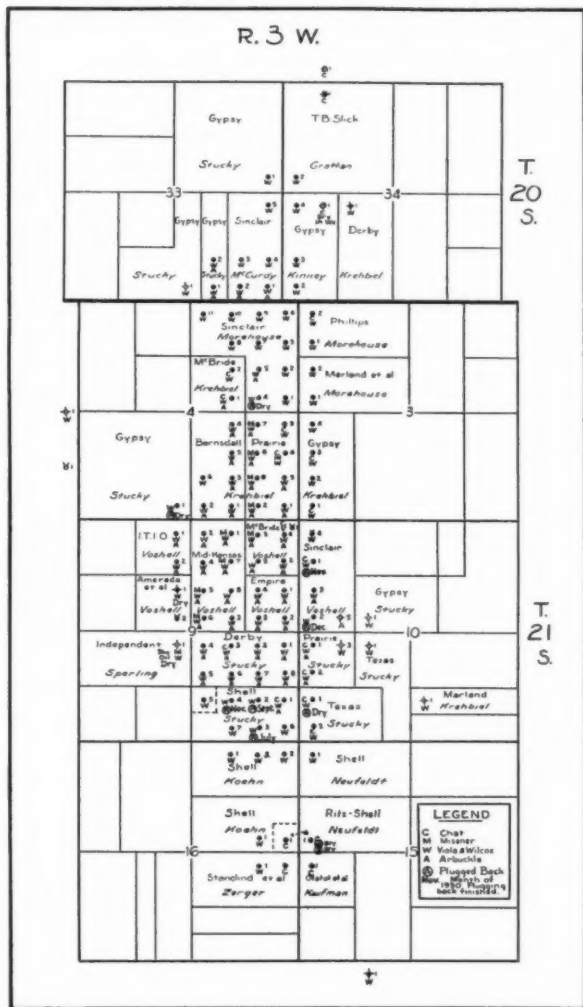


FIG. 7.—Map of Voshell field, as of October, 1931, to show reservoir formations in which wells were produced or were completed. Width of area mapped, 2 miles.

rate of heading up suggested initial production of 150 barrels. The original pressure was sufficient to support a static head of 1,800 feet of oil, devoid of any appreciable amount of gas. Practically none of the wells in the Voshell field has been shot. Results from the Simpson limestone in near-by fields have been favorable after shooting.

The chief producing member in the Simpson group is the "Wilcox sand," member *F* (Fig. 3). Its thickness in the field persists at approximately 20 feet. The lithology varies from friable to quartzitic, with the latter condition more prevalent in the northern half of the field. The wells had initial production swabbing tests ranging from 200 to 1,800 barrels. The wells completed in the "Wilcox sand" are designated in Figure 7.

The glauconitic sandstone, member *D*, and the basal conglomeratic zone, member *A*, were observed to have been saturated and to have had original pressures similar to that of the "Wilcox sand." The common practice was to complete the wells in the Arbuckle limestone without testing these members separately. A few wells were completed in member *D*, but were already producing from the "Wilcox sand."

The Arbuckle limestone had at least two fairly persistent pay streaks, each less than 3 feet thick. One streak occurred at a penetration of 6 feet and the lower streak occurred at a penetration of 10 feet. The streak was apparently leached, dolomitized limestone; the non-productive section comprised dense, cherty beds. The initial production in swabbing tests ranged from 700 to 2,100 barrels. The wells would flow about 25 barrels per hour. No appreciable amount of free gas was observed. In Figure 7 the wells are designated which were completed in the Arbuckle limestone, also those in which the Arbuckle limestone was later plugged off due to an excess of water.

RELATION OF OIL AND GAS OCCURRENCE TO GEOLOGIC STRUCTURE

All the production to date in the Voshell field has been recovered from pre-Pennsylvanian sediments. The folding is relatively intense compared with the average field in Kansas. The reservoir horizons appear to have been saturated with oil and gas within the limits of closure as far as those limits are now measurable. Below those limits the reservoir horizons are saturated with water. The writer has no theories of migration or origin to offer.

The age of the folding in the Voshell field is closely comparable

with that in several other fields directly related to anticlinal folding in Oklahoma and Kansas.¹

The faulting along the western side of the field is considered important. As shown in Figure 8, the greatest recoveries per acre, and the largest average daily production per well, occur adjacent to the fault zone, along the eastern or upthrown side. The explanation of this relation is that the water movement which has been observed to be from the east toward the west is the chief propulsive agent and results in a natural or uncontrolled water-drive.

Oil and gas in the "chat" occur in upfolded, truncated wedges, illustrated in Figure 5.

Commercial production from the "Misener sand," Simpson limestone, and "Wilcox sand," appear to date to be confined to the part of the anticline bounded by the -1,950-foot contour of Figure 4. Commercial production from the Arbuckle limestone is likewise observed to be restricted to the area within the -1,900-foot contour.

SUBSURFACE WATER CONDITIONS

In the part of the field where commercial production is obtained from Ordovician formations, the lowest water-bearing formation to be cased off occurs in the lower part of the Lansing-Kansas City group (Fig. 2). Water may eventually be produced from the "chat" in this part of the field, in which case the Ordovician formations are protected by the 7-inch producing string which is cemented on the top of the Simpson limestone or set on the "Misener sand."

All the pre-Pennsylvanian reservoir horizons had approximately a uniform original hydrostatic level, which was 400-500 feet above sea-level.

In Figure 5, the oil-water contact is drawn for the "chat" and for the Ordovician formations. Observations have indicated that the Ordovician formations had a common oil-water contact. The rate of water movement in adjustment toward volumetric replacement of oil withdrawals apparently is distinct for each reservoir horizon. The rapid decline of formation pressure in the "Wilcox sand" following the early intense development of the field seems to indicate a slow rate of water adjustment. The rate of water adjustment in the Arbuckle limestone, on the other hand, apparently has been rapid, and varied in different parts of the field. The oil-water contact in the Arbuckle

¹ John R. Reeves, "El Dorado Oil Field, Butler County, Kansas," *Structure of Typical American Oil Fields*, Vol. II (Amer. Assoc. Petrol. Geol., 1929), p. 167.
T. E. Weirich, "Cushing Oil and Gas Field, Creek County, Oklahoma," *ibid.*, p. 406.

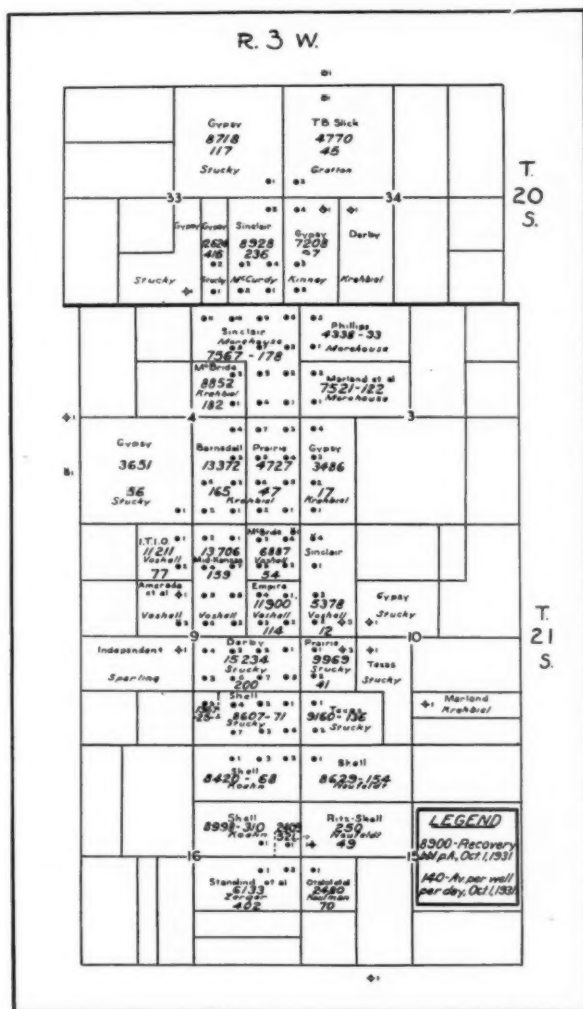


FIG. 8.—Map of Voshell field, as of October, 1931, to show recovery per acre by leases, and daily average production per well by leases for month of September, 1931. Width of area mapped, 2 miles.

limestone apparently became irregular following development in the field, and some of the wells had to be plugged back in a short time due to an excess of water.

In wells where the entire section was exposed from the "Misener sand" to the Arbuckle limestone, the Arbuckle water continued to come in even when the wells were shut in during proration. The low formation pressure in the "Wilcox sand" permitted the Arbuckle water to enter the sandstone. In some wells as much as four weeks of pumping was required to de-hydrate the "Wilcox sand" after the Arbuckle limestone was plugged off.

WATER ANALYSES

The presence of hydrogen sulphide in the water from the Ordovician formations seems to suggest that, in time, corrosion of the pumping equipment will occur, as has occurred at El Dorado and other fields.¹

The analyses for the various horizons are considered typical for the Voshell field. The water from the "chat" has a concentration in parts per million of about five times that for the water from the Ordovician formations. Only negligible differences were observed in various analyses of water from the "Wilcox sand" and from the Arbuckle limestone.

In general, the water from Ordovician formations was practically uniform whether taken from areas on the upthrown or the downthrown side of the fault zone (Fig. 4). There is one exception, the Gypsy Oil Company's Stucky No. 1, SE. $\frac{1}{4}$, SE. $\frac{1}{4}$, SW. $\frac{1}{4}$, Sec. 4, where the well penetrated the "Wilcox sand" apparently on the upthrown side adjacent to the fault, in which the water had a concentration more than 30 per cent in excess of the average for this formation. The well encountered no "chat." However, the writer infers that the greater concentration resulted from infiltration of "chat" water which traveled

TYPICAL "MISSISSIPPI LIME" WATER, MARCH 24, 1930

	Parts per Million	Reac. Value Per Cent
Na	44,208	39.17
Ca	7,660	7.80
Mg	1,818	3.03
SO ₄	trace
Cl	87,000	50.00
HCO ₃
CO ₂
Total	140,686	100.00

¹ R. Van A. Mills, *U. S. Bur. Mines Bull.* 233 (1925), pp. 55-57.

TYPICAL "WILCOX SAND" WATER, APRIL 19, 1930

	<i>Parts per Million</i>	<i>Reac. Value Per Cent</i>
<i>Na</i>	9,383	41.76
<i>Ca</i>	976	4.98
<i>Mg</i>	387	3.26
<i>SO₄</i>	393	.84
<i>Cl</i>	16,860	48.67
<i>HCO₃</i>	293	.49
<i>CO₂</i>
Total	28,292	100.00

TYPICAL ARBUCKLE LIMESTONE WATER, JULY 28, 1930

	<i>Parts per Million</i>	<i>Reac. Value Per Cent</i>
<i>Na</i>	8,427	38.20
<i>Ca</i>	1,647	8.58
<i>Mg</i>	376	3.22
<i>SO₄</i>	1,140	2.47
<i>Cl</i>	16,110	47.36
<i>HCO₃</i>	102	.17
<i>CO₂</i>
Total	27,802	100.00

down the fault and from the downthrown "Mississippi lime" located immediately west of the well. Qualitatively, hydrogen sulphide is present in water from "Wilcox sand" and Arbuckle limestone.

DRILLING PRACTICE

Well spacing.—The only disadvantage in the 10-acre spacing was possibly along the fault trend on the western side of the field, where locations spaced closer to tract boundaries probably would have averted drilling dry holes.

Equipment used.—In a total of 95 completions, 19 wells were drilled entirely with standard tools, 75 were drilled with rotary tools either to the top of the "chat" or to the top of the Simpson limestone, and completed with standard tools, and one well was completed with rotary tools. For power, both electricity and steam were used in the field. Electricity was slightly cheaper than the cost of metered gas for fuel. Multiple-cylinder gas motors were used in one operation, with drilling time and costs comparable to electric or steam power costs.

Cable-tool drilling.—In the territory cable-tool drilling had involved considerable under-reaming, and some operations "ran out of hole" before reaching the Arbuckle limestone. By revising the well plans, the standard-tool operations were successful in the Voshell field. At the time of intense development the cost of cable-tool drilling

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was approximately \$9,000.00 per well less than that of rotary-tool drilling. In the light of impending proration, some operators found it practicable to effect this saving.

COMPOSITE WELL PLAN, CABLE-TOOL DRILLING

Hole Diameter in Inches	Pipe Diameter in Inches	Pipe Weight per Foot in Pounds	Depth in Feet	Horizon	Remarks
	20	90	125		Drive pipe
18	15 $\frac{1}{4}$	70	700		Formation shut off
15	13 $\frac{3}{8}$	54.5	1,550		Formation shut off
12	10 $\frac{3}{4}$	45.5	2,365		Under-reamed from top of Douglas group
10	8 $\frac{5}{8}$	32	2,950	"Chat"	Cemented
8	7	24	3,230	"Misener sand" or Simpson limestone	Formation shut off, or cemented
6			3,330	Arbuckle lime- stone	
5			3,340		Total depth

The 15 $\frac{1}{4}$, 13 $\frac{3}{8}$, and 10 $\frac{3}{4}$ -inch strings were pulled. In a few wells 5 $\frac{1}{8}$, 18-pound, inserted liners were run on the top of the Arbuckle limestone to prevent the hole from bridging at the top of the Simpson group, member G (Fig. 3).

The average drilling time, including rigging up, was approximately 60 days, with a minimum of 50 days. The average cost of a well completed on the pump was about \$41,000.00 with the salvaged material deducted.

Rotary drilling.—Of 75 rotary operations about 50 were standardized on the top of the Simpson limestone, 24 were standardized on the top of the "chat," and one well was "cored-in" to the "Wilcox sand." With a shortage of water, the electric power had an advantage over steam power. The chief advantage of rotary drilling is considered to be the better facilities afforded to drill through the "chat," where heavy gas volumes and pressures were encountered, and to drill through the Kinderhook shale, where oil had been encountered, to the "chat." The rigid proration enforced reduced the advantage of shortened drilling time.

The common practice was to plumb the drillpipe while spudding, to carefully cement the surface pipe below the unconsolidated sand of the McPherson formation, to run acid-bottle tests at intervals of 1,000 feet or less, and to keep rotary samples below a depth of

about 2,000 feet. The use of heavy 9-inch drill collars in some operations appeared to speed the drilling and to assist in drilling vertical hole. With regular rock bits the sticky shale balled-up on the cones and caused slower drilling than was experienced in drilling in limestone. Coring in the "chat" was in general a failure. No drillstem tests were conducted, although, in the case of a large gas volume in the "chat" and also the presence of a hole full of water in the "chat" in another operation, data from a test would have been economically important.

In a few operations, rotary drilling proceeded to the top of the Simpson limestone, the 8 $\frac{5}{8}$ -inch pipe was swung and cemented at the top of the "chat," the hole was swabbed until the well cleaned itself, and then the 7-inch pipe was cemented on the top of the Simpson limestone. This plan permitted the "chat" gas to be produced and avoided the disadvantages of drilling the Kinderhook shale with standard tools.

COMPOSITE PLAN, ROTARY-TOOL DRILLING

<i>Hole Diameter in Inches</i>	<i>Pipe Diameter in Inches</i>	<i>Pipe Weight per Foot in Pounds</i>	<i>Depth in Feet</i>	<i>Horizon</i>	<i>Remarks</i>
20	15 $\frac{1}{2}$	70	170	Wellington shale	Surface pipe, cemented up to collar, set 60 hours
11	8 $\frac{5}{8}$ seamless	32	3,230	Simpson limestone	Cemented. Standardized
8			3,270	"Wilcox sand"	
6			3,330	Arbuckle limestone	
5			3,340		Total depth

The drilling time with rotary tools, including rigging-up, standardizing, and completing, averaged about 40 days. In several operations re-cementing the surface pipe, fishing for slips, drillpipe, et cetera, and plugging-back holes which deviated too much from vertical, caused the drilling time to increase a week or more. The wells completed on the pump cost approximately \$50,000.00. Since the time of intense development all costs have decreased very materially both in rotary and cable-tool drilling.

Casing used.—Only one case of collapsed pipe occurred in rotary operations. In cable-tool drilling some trouble occurred in driving the 20-inch pipe. The lack of thick sandstone formations permitted the big pipe to be re-run ten or twelve times in cable-tool drilling.

PRODUCTION METHODS

Two plans of development or exploitation were established. In Sections 4 and 9, the formations from the "Misener sand" to the Arbuckle limestone were exposed in wells. During the months when the daily allowable per well was about 100 barrels, the water from the Arbuckle limestone flooded back into the "Wilcox sand." In Sections 33 and 34, however, the wells were not deepened to the Arbuckle limestone until after proration was lifted, and by pumping to capacity the operators could prevent the water from the Arbuckle limestone from heading up to the point of creating a flooding pressure on the "Wilcox sand."

Proration methods.—The plan of proration first adopted was to take potentials by swabbing. Then the field was put on the pump, with tubing sizes and pumping strokes limited for taking potential tests. No rules were made concerning acreage units or penetration into producing formations.

Results of proration.—The graph (Fig. 9) illustrates the history of production. The pipeline facilities were insufficient to permit the field to produce to capacity even on the pump. The potential tests were taken to allow all the leases to have connections and to prorate the wells equitably, and apparently the tests had no particular significance in case the pipeline runs were raised or lowered with regard to future behavior of wells.

It is interesting to observe the relationship between the potential curve and the pipeline-runs curve in Figure 9. From March 1 to July 1, 1930, the potential curve declined when the runs ranged between 200 and 400 barrels per well per day. When the runs were lowered to approximately 100 barrels per well per day, the potential curve inclined in response. When the 5-day production test was taken in February, 1931, and proration was lifted, the capacity per well per day was only 260 barrels, and thereafter to October 1, the field's daily average per well slowly declined. These observations might suggest that in case the pipeline runs had been maintained at an average of approximately 250 barrels per well per day during 1930, the potential curve would have declined similarly to the dotted line on Figure 9.

Pumping equipment.—The Voshell field was one of the first to adopt extensive use of pumping units comprising steel fronts, jack-shaft clutch, reversible belt drive, and band wheel with rotary, de-

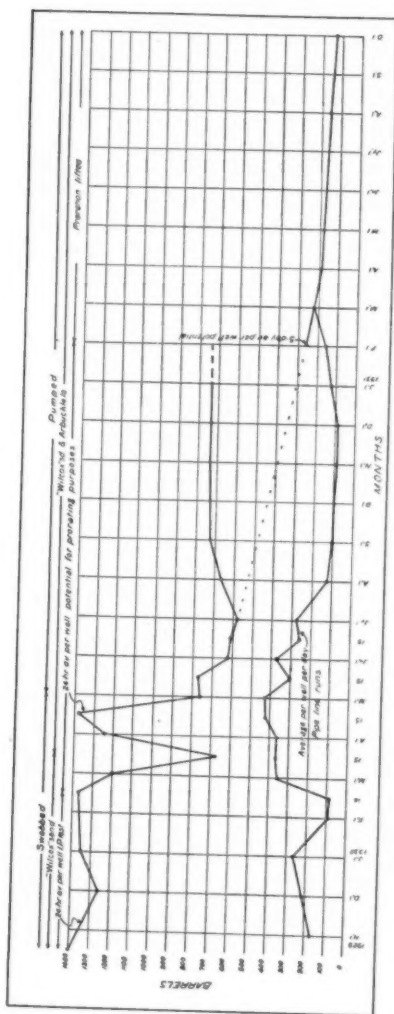


FIG. 9.—Production graph, Voshell field, October, 1929, to October, 1931; compiled from proration reports and operators' records.

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tachable counterbalance. Both electric motors and gas engines were used as prime movers.

Both 2½-inch and 3-inch tubing strings were used, with the strings run on bottom. The plunger-type working barrels were used commonly, although some leases were equipped with "fluid-packed pumps" and one submerged, electric rotary pump was installed.

DISTILLATION SHEET ON VOSHELL,

KANSAS, CRUDE

January, 1931

Sample marked: Voshell, Kansas, crude
Gravity, 42.5 A. P. I. Color, dark green, Odor, sour
U. S. Bureau of Mines
Hempel distillation
First drop 88° F.

<i>Per cent Cut</i>	<i>Sum per cent</i>	<i>Temp. °F.</i>	<i>A. P. I. Gravity</i>
3.0	3.0	Up to 122	
5.5	8.5	122-167	
5.5	14.0	167-212	79.7
8.0	22.0	212-257	
6.2	28.2	257-302	58.9
5.2	33.4	302-347	
6.6	40.0	347-392	
3.0	43.0	392-420	49.0
	Cut		
8.2	51.2	420-482	43.1
6.5	57.7	482-527	39.6
	Cut		
41.5 Fuel oil			26.1

Recapitulation

<i>Per Cent</i>	
43.0	62.7 A. P. I. Gasoline
14.7	41.6 A. P. I. Kerosene
41.5	26.1 A. P. I. Fuel Oil
.8	
100.00	

Remarks: This crude evolved hydrogen sulphide all through the distillation.

GEOLOGICAL NOTES

ACKERMAN FORMATION IN ALABAMA¹

In 1925, I published a short paper on the correlation of the Eocene formations in Mississippi and Alabama,² in which the Ackerman formation of Mississippi is tentatively correlated with the Nanafalia formation of Alabama because it is overlain and underlain by formations of the same ages in the two states. However, the exact equivalence of the Ackerman and the Nanafalia is not readily determinable because they are partly overlapped near the state line.

In western Alabama, according to Smith,³ the Nanafalia formation is separable into three parts; an upper "pseudoburhstone" member, a middle *Ostrea thirsae* bed, and a basal lignitic member that Langdon, in the same volume,⁴ called the "Coal Bluff series" and that Brantly⁵ later called the "Coal Bluff beds." I followed Smith's three-fold division of the Nanafalia formation in the "Geology of Alabama," although I suspected that the lower member does not logically form part of the Nanafalia.⁶

G. I. Adams, while studying the Nanafalia in detail, came to the conclusion that the "Coal Bluff beds" should not properly be included in the formation because there is "clear evidence of a transgression of the sea with the introduction of greensands and marine fossils in the succeeding members."⁷ Evidence of this transgression is the absence of the "Coal Bluff beds" in eastern Alabama and along the Chattahoochee River, where, as stated on page 262 of the "Geology of Alabama," the *Ostrea thirsae* zone of the Nanafalia overlaps the "Coal Bluff beds" and the Naheola formation of the Midway group and lies directly on the Clayton limestone. Adams discovered that the "Coal Bluff beds" are not completely overlapped near the Mississippi

¹ Manuscript received, December 17, 1932. Published by permission of the director, United States Geological Survey.

² C. W. Cooke, *U. S. Geol. Survey Prof. Paper 140* (1925), pp. 133-36.

³ E. A. Smith, L. C. Johnson, and D. W. Langdon, "Report on the Geology of the Coastal Plain of Alabama," *Alabama Geol. Survey* (1894), Pl. 170.

⁴ *Ibid.*, p. 421.

⁵ J. E. Brantly, *Alabama Geol. Survey Bull. 22* (1920), p. 149.

⁶ C. W. Cooke, *Alabama Geol. Survey Special Rept. 14* (1926), p. 258.

⁷ Unpublished manuscript sent me for criticism six weeks before his death on September 8, 1932.

border, as I had supposed after a brief reconnaissance, but that they can be traced westward across the state line into the Ackerman formation. To this extent he verified my tentative correlation of the Ackerman with the Nanafalia.

The Ackerman formation of Mississippi closely resembles the "Coal Bluff beds" of western Alabama. Both consist chiefly of black laminated clay, lignite, and cross-bedded sand. Both the Ackerman and the "Coal Bluff beds" are quite unlike the typical part of the Nanafalia formation (*Ostrea thirsae* zone) and also unlike the "pseudobuhrstone." Therefore it seems reasonable to suppose that the Ackerman is not equivalent to the entire Nanafalia formation, but only to the "Coal Bluff beds," with which, according to Adams, it is continuous. However, as the "Coal Bluff beds" are thinner than the Ackerman formation, it is quite likely that they represent only the lower part of the Ackerman. These relationships are shown in Table I.

If the "Coal Bluff beds" are to be taken out of the Nanafalia, it seems fitting that they should be called by the name Ackerman formation, by which they are known in the adjoining state. The Ackerman, then, extends from northern Mississippi, where it is overlapped by the Holly Springs sand (of Wilcox age), to an undetermined point east of the Alabama River, where it is overlapped by the restricted Nanafalia formation.

Adams was of the opinion that the beds here called Ackerman formation belong in the Midway group rather than in the Wilcox group, to which the Nanafalia belongs, because he detected no evidence of widespread unconformity at their base and because of the transgression of the Nanafalia sea across them, which transgression seems a logical time to begin a new epoch, that of the Wilcox group. If the Ackerman is Midway, the sequence of events in Midway time is as follows: first, a transgression of the sea attended by the deposition of the Clayton limestone; next, deposition of the marine Porters Creek clay in Mississippi and of the equivalent Sucarnoochee clay in Alabama; then, shoaling of the sea and deposition of the Tippah sandstone member of the Porters Creek in Mississippi and of the micaceous, sandy Naheola formation in Alabama; finally, during Ackerman time, alternation of marine and continental conditions, attended by the deposition of cross-bedded sand and the accumulation of lignite. Similarly, the Wilcox group began with a transgression of the sea in the east and the formation of the oyster beds of the Nanafalia; later, westward shifting of the area of transgression and the overlap of the

TABLE I
DIVISIONS OF MIDWAY AND WILCOX GROUPS IN ALABAMA AND MISSISSIPPI

	Old correlation		New correlation	
	Alabama	Mississippi	Alabama	Mississippi
Wilcox group	Hatchetigbee formation	Grenada formation	Hatchetigbee formation	Hatchetigbee formation (in Lauderdale County)
	Bashi formation	Bashi formation	Bashi formation	Bashi formation
	Tuscahoma sand	Holly Springs sand	Tuscahoma sand	Holly Springs sand
	Nanafalia formation	Ackerman formation	Nanafalia restricted in "Pseudobuhrstone" <i>Ostrea thirsae</i> zone	Overlapped
	Naheola formation	Tippah sandstone member	Overlapped	Ackerman formation
			Ackerman formation	
			Naheola formation	
	Sucarnoochee clay	Porters Creek clay	Sucarnoochee clay	Tippah sandstone member Porters Creek clay
	Clayton formation	Clayton limestone	Clayton formation	Clayton limestone
Midway group				

marine Tuscaloosa sand in western Alabama and of the Holly Springs sand in Mississippi; then, alternation of continental and marine conditions and the accumulation of the lignite, shell beds, and clay of the Bashi formation; and, finally, the accumulation of the carbonaceous clay and sand of the Hatchetigbee formation in Alabama and eastern Mississippi. The Claiborne and Jackson groups also began with transgressions of the sea.

Whether the Ackerman formation should be referred to the Midway group or to the Wilcox group may ultimately be determined by a study of the fossil fauna and flora. Search should be made for shells in those beds that appear to be marine for comparison with the large and distinctive Midway and Wilcox faunas. Part of the flora of the Ackerman has already been studied by Berry,¹ who lists 36 species from it, as compared with 257 in the Holly Springs sand. Of these 36, 13 are peculiar to the Ackerman and 23 occur also in the Holly Springs sand or younger beds. Valid conclusions as to the degree of relationship to the Wilcox floras can scarcely be drawn from this meager representation of the Ackerman flora. No comparison with the Midway flora can now be made because no recognizable plants have yet been described from deposits of undoubted Midway age. A collection of ten species of plants from Earle, Texas, which were doubtfully referred by Berry² to the Midway group, has one species (*Terminalia hilgardiana* Berry) in common with the Ackerman flora, but this plant-bearing bed is now known to be of Wilcox age.³ Because of this lack of faunal and floral evidence as to the age of the formation, it seems preferable to continue, for the present, to classify the Ackerman as Wilcox although the possibility of its being Midway should be kept in mind.

C. WYTHE COCKE

UNITED STATES GEOLOGICAL SURVEY
WASHINGTON, D. C.
December, 1932

¹ E. W. Berry, *U. S. Geol. Survey Prof. Paper 91* (1916), p. 141.

² E. W. Berry, *ibid.*, p. 9.

³ Julia Gardner, *Geologic Map of Texas* (preliminary edition), 1932.

REVIEWS AND NEW PUBLICATIONS

La Géologie et les Mines de la France d'outre-Mer (The Geology and the Mines of Overseas France). By 14 authors. A publication of Bureau d'Études géologiques et Minières coloniales. (Soc. d'Editions géographiques, 184 Boulevard Saint-Germain, Paris, 1932.) 604 pp., 38 figs., 2 pls. 6 $\frac{3}{8}$ ×9 $\frac{5}{8}$ inches. Paper. Price, 60 francs.

The semi-official Bureau d'Études géologiques et Minières coloniales has organized a series of lectures on the geology and mineral resources of the French possessions. These are printed in this volume. Short chapters have been added on less important colonies evidently not covered by the lectures. Among the authors are some of the best known French geologists. The illustrations are mostly maps and a few cross sections. To each chapter is added a bibliography. Thus a handbook on the geology of the French colonies was created, which is indispensable to anybody interested in these areas.

The following chapters are of special interest to petroleum geologists.

1. "Algérie et Tunisie" (Algeria and Tunis), by L. Joleaud.
2. "Maroc" (Morocco); "Maroc septentrional" (Northern Morocco), by P. Fallot; "Maroc central et méridional" (Central and Southern Morocco), by L. Neltner.
4. "Afrique occidentale française et Togo" (French West Africa and Togoland), by Henry Hubert.
5. "Afrique équatoriale française et Cameroun" (French Equatorial Africa and Kamerun), by André Demay.
7. "Madagascar"; "Les terrains sédimentaires de l'ouest de Madagascar" (The Sedimentary Terrains of Western Madagascar), by F. Blondel.
10. "États du Levant sous mandat français" (Syria, under French mandate), by L. Dubertret.
12. "Indochine française" (French Indo-China), by Charles Jacob.
13. "Nouvelle-Calédonie" (New Caledonia), by M. Glasser.
18. "Martinique et Guadeloupe."
20. "Le pétrole dans les possessions françaises" (Petroleum in the French Possessions), by M. Léon Bertrand.
21. "Statistique de la production minérale de la France d'outre-mer" (Statistics of the Mineral Production of Overseas France).

Chapter 20 deals with the origin and accumulation of oil, facies of oil series, et cetera, and then discusses the oil possibilities of the different possessions more in detail than the other chapters.

The only actual oil production is in northern Africa, Algeria having produced 1,600 tons of crude in 1930 and Morocco 20 tons. In the vicinity of Tliouanet, southeast of Oran, a number of wells produce from different sand lenses in the middle Miocene ranging in thickness from 25 to 170 meters. The little production of Tselfat west of Fez comes from the lower Jurassic. Seepages and showings of oil and gas in test wells are numerous throughout the territory. They occur in different parts of the Tertiary and in the Upper Cretaceous, ordinarily on or near anticlines. The folding is in most places

very complicated, of the Alpine type with overthrusts. It will take considerable drilling combined with the most careful geological work to determine the oil possibilities of northern Africa.

Limestones near Cape Verde contain some bitumen, and cavities in the upper Oligocene limestone of Dakar contain some crude oil. Limestones probably of Cretaceous age and Tertiary sands on the Ivory Coast are impregnated with bitumen. Very little is yet known about the geology of these areas.

Oil seepages occur in a Cretaceous series along the coast of Kamerun and the French Kongo, which lies on thick sandstones belonging to the Permian or Triassic or possibly the Jurassic. The strata are nearly horizontal and a search for favorable structure is now under way.

Though most of Madagascar consists of crystalline rocks, there is a border of sediments with a maximum width of 100 miles along the west coast. At the base there is the Karroo series extending from the Carboniferous to the lower Jurassic and having a thickness of about 2,500 meters. They consist of shale, sandstone, and conglomerate, with some coal and very little limestone. The next series comprises Jurassic, Lower and Middle Cretaceous. It is calcareous in the lower part, but the Cretaceous is represented by light-colored shales with sandstones in the upper part. Flows of basalt complete this series. Separated by a marked unconformity follows Upper Cretaceous, consisting of shale in the lower part, sandstones in the middle, and chalk in the upper part. The Eocene is represented by sandstones and by limestones in the southwest. Oligocene is present only in the extreme north part of the island. The Miocene thickens toward the southwest. Recent sediments form a coastal plain of considerable width. In several localities the Triassic is bituminous sand containing, on the average, 10 per cent of heavy oil. These large deposits have not yet been worked, as they are a long way from the world markets and can not compete with cheap crude. A number of test wells have been drilled near these deposits without favorable results. These tar sands are evidently former oil deposits, from which the lighter constituents have evaporated. Important oil fields are likely to be discovered, if these oil sands are found under cover. Of course the tar sands of the Trias may have been at the surface in former time, for example during the period represented by the Cretaceous erosional unconformity, and may have lost their light oil before the present cover was deposited. Then the basaltic intrusions may have acted unfavorably. The territory is an area of low dips, and geological investigation so far has revealed only two favorable anticlines. The more prominent of these, with dips of 4° and 5°, will be tested.

The greater part of the island of Martinique is covered with volcanic rocks. Miocene occurring in the east and southeast part of the island is considered by Bertrand as having oil possibilities. The facies is favorable and one anticline is known. Asphalt-coated pebbles on the coast indicate a submarine seepage.

In the northwestern part of New Caledonia seepages of oil and showings in test wells occur in the Eocene, which has a thickness of several thousand meters. It consists largely of shale, with sandstone and conglomerate, some lenticular limestone and gypsiferous marls, and volcanic rocks. The structural conditions are not well known, but are complicated, Triassic having been thrust over the Eocene.

In French Indo-China, in a locality northwest of Hanoi, droplets of oil are found in geodes in a pre-Carboniferous limestone. The rocks were strongly folded in Paleozoic time and again in the Tertiary. In most anticlines old rocks, not likely to contain oil, come to the surface.

Bertrand comes to the conclusion that the best chance for supplying France with crude oil in the near future is from the concession in Iraq. This proved area may extend into Syria, which is under French mandate. Though the geology of Syria is not very well known, conditions seem to be less favorable. Instead of the long northwest-southeast anticlines of Iraq, short anticlines extend east and west or southwest and northeast. The anticline of the Sinjar Hills, probably the most prominent, is eroded down to the Cretaceous, though the Iraq production is in the Miocene. Farther south the thickness of the sediments decreases. That there are possibilities as far west as the coast of the Mediterranean is indicated by a seepage in the Miocene near Alexandrette. The asphalt of Latakiah in Cretaceous limestone is supposed to be an impregnation from the adjoining Miocene.

Though one can not be very optimistic about the French possessions producing large quantities of oil, additional geological work coupled with the drilling of test wells may change the picture.

EDWARD BLOESCH

TULSA, OKLAHOMA
January 3, 1933

Internationaler Geologen und Mineralogen Kalender (World Directory of Geologists and Mineralogists), compiled by RUDOLPH CRAMER: Published by the German Geological Society, at the Press of Ferdinand Enke, Stuttgart, December, 1932 (dated 1933). Price RM. 8.

This most valuable little book is a world directory of geologists and geological institutions and societies. It lists: (1) the names and addresses of about 7,000 geologists and related scientists; (2) the various state and federal geological and allied surveys of the world, the address of each, its staff, each man's rank and specialty, the publications issued by the survey, the sales agent for the survey publications; (3) the various school and museum geological departments of the world, the staff of each, and each man's rank and specialty; and (4) the geological and associated societies of the world, the address of each; and for many of the societies, the secretary or officers of the society, the publications issued by the society, and its dues.

It is most convenient to be able to reach for a single little volume to see whether such a state has a geologic survey, what the official name of such a state survey is, and where its headquarters is, who is professor of geology (or paleontology, or geophysics) at such a university, or what the address of such and such a foreign geologist may be. The reviewer's copy of the preceding (1925-26) edition of the *Geologen Kalender* has been in constant use and he can see much use for his copy of its most excellent successor.

DONALD C. BARTON

HOUSTON, TEXAS
December, 1932

Origin and Environment of Source Sediments of Petroleum. By PARKER D.

TRASK assisted by HARALD E. HAMMAR and C. C. WU. 323 pp., 1 pl., 38 figs. Fabrikoid, 6×9. Gulf Publishing Company, Houston, 1932. Price, \$6.00.

This volume presents in full the results obtained in Project 4 of the Research Program of the American Petroleum Institute. The project was essentially a worldwide search for sediments now accumulating which might be regarded as possible source beds of petroleum in the future. Approximately 2,000 samples were studied, representing 1,580 localities and 150 regions and covering "practically every type of environment of deposition of sediments in the world."

The scope and thoroughness of the inquiry are shown by the chapter headings, which include: Collection and Preparation of Samples; Measurement of Organic Content; Distillation Tests; Texture of Sediments; Calcium Carbonate Content; Relation of Organic Matter to Environment; Detailed Analyses of Organic Constituents; Change of Organic Content with Depth; Comparison of Past and Recent Sediments; Miscellaneous Results; Theoretical Considerations. The appendix contains tables giving general data on all the samples, their classification according to environment, and the results of chemical and mechanical analysis and the various tests—a most impressive and valuable body of fundamental data.

Fortunately nitrogen, which can be determined quickly and accurately, was found to give the best index to the organic content. The large folding plate showing nitrogen distribution in recent sediments throughout the world is in itself an excellent conspectus of the results. Organic content increases with fineness of texture and this in turn is controlled by the configuration of the bottom. Hence fine texture is no proof of either deep water or distance from the shore.

Most sediments are poor in organic matter. Five of the richest yielded no trace of petroleum when extracted with carbon tetrachloride. The richest sample distilled gave 3.4 gallons of oil per ton, or 1.3 per cent by weight. The limy sediments yield more oil and gas per unit of nitrogen than do the clastics. The carbonate content is correlated with surface salinity of the sea, temperature being only a minor factor. The supply of organic matter depends on the abundance of phytoplankton, and this in turn is controlled by the upwelling of deep water. Investigation of the constitution of the organic matter in sediments furnishes the basis for comparison as similar work progresses on the sediments of the past. Preliminary comparison shows, for example, that ether will extract three times as much organic matter from the older sediments as from recent deposits.

The foregoing selections merely suggest some of the striking topics and conclusions. The author makes it clear that the inquiry has not yet solved the problem of source material of oil. It constitutes the first half of a program that must include also the sediments of the past and the transformations they have undergone, particularly their organic content. The work has made valuable contributions to the fundamental problems of the science. The able geologists who planned the inquiry and under whose advice and direction the work has been carried out have wisely sought a deeper insight into basic

principles as giving promise of the most valuable results in the particular field of petroleum geology. Hence this volume has an interest and value beyond the limited field. Students of sedimentation and stratigraphy, in particular, will find in it many things pertaining to their problems.

Praiseworthy is the author's careful distinction between the facts, on the one hand, and inferences and speculations, on the other. Many of the conclusions are definitely stated to be preliminary or tentative; with the basic facts before him the reader may judge for himself concerning their validity.

The book is well printed and bound and the text is remarkably free from errors. Besides the exhaustive tables in the appendix there are 35 tables in the text, many of them summarizing extended results; also 38 figures, chiefly maps and graphs. A few of the maps have been reduced a little too much for clearness. The tables in the appendix are printed in small type, but they are clear and usable.

J. VOLNEY LEWIS

WHITE PLAINS, NEW YORK
January 14, 1933

RECENT PUBLICATIONS

CALIFORNIA

"A Report on Playa Del Rey Oil Field," by Cecil L. Barton. *California Oil Fields*, Vol. 17, No. 2 (October-December, 1931), pp. 5-15; 4 pls. State Oil and Gas Supervisor, San Francisco, 1932.

GENERAL

"Mining Petroleum by Underground Methods: a Study of Methods Used in France and Germany and Possible Application of Depleted Oil Fields under American Conditions," by G. S. Rice. *U. S. Bur. Mines Bull.* 351 (1932). 159 pp., 38 illus. Price, \$0.15.

"Summary Information on the State Geological Surveys and the United States Geological Survey," *National Research Council Bull.* 88. Compiled under the direction of the National Research Council Committee on State Geological Surveys, by M. M. Leighton. (Washington, D. C., November, 1932.) 136 pp. Price, \$1.00.

"Report of the Committee on Sedimentation, 1930-1932," *National Research Council Bull.* 89. Prepared under the auspices of the Division of Geology and Geography, by W. H. Twenhofel, committee members and others. (Washington, D. C., November, 1932.) 229 pp. Price, \$1.00.

Petroleum Vademecum, 9th ed. (1932). International petroleum tables edited by Robert Schwarz. Vol. I (248 pp.) contains chemical-physical tables, oil-field engineering data, and oil tariffs. Vol. II (365 pp.) contains statistics on production, import, and export. 5×6½. Cloth. (Verlag für Fachliteratur, Wilhelmstr. 147, Berlin, S. W. 68.) Price, M. 24; \$6.00.

"Some Preliminary Experiments on Oil Recovery Processes," by William L. Russell. *New York State Mus. Circ.* 8 (Albany, November, 1932). 30 pp.

"Zur Geochemie der Ölbildung" (Geochemistry of Oil Formation), by

Stanislaw Zuber. *Petrol. Zeits.*, Vol. 28, No. 48 (Berlin, December 1, 1932), pp. 1-5.

"Evidence Indicating the Limits of Triassic in Kansas, Oklahoma, and Texas," by Robert Roth. *Jour. Geol.*, Vol. 40, No. 8 (Chicago, November-December, 1932), pp. 688-725.

HUNGARY

"Die geologische Karte Ungarns" (The Geological Map of Hungary), by Karl von Papp. First part of text. *Földtani Szemle* (Geological Review, Budapest), Vol. I, Pt. 1 (1932), pp. 89-128.

LOWER PLIOCENE IN SANTA MARIA DISTRICT, CALIFORNIA

CORRECTION

In the February, 1932, *Bulletin*, Vol. 16, No. 2, in the paper by William W. Porter II, "Lower Pliocene in Santa Maria District, California," on page 139, in the second new paragraph, the second sentence should be, "These beds are exposed on the Sisquoc-Tinaquaic line fence, approximately 3 (not 6) miles east from the northwest corner of the Tinaquaic Grant."

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to J. P. D. Hull, business manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

FOR ACTIVE MEMBERSHIP

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Robert D. Sprague, Fort Worth, Tex.

H. Smith Clark, Wesley G. Gish, Frederic A. Bush

EXECUTIVE COMMITTEE MEETING, NOVEMBER 29, 1932

The executive committee met at Houston, Texas, November 29, 1932, with all members in attendance: F. H. Lahee, chairman; W. B. Heroy, secretary; L. P. Garrett; R. J. Riggs; and R. D. Reed.

The following appointments were announced: Alexander Deussen to the committee on geologic names and correlations; and A. E. Brainerd, W. F. Chisholm, Marvin Lee, and S. E. Slipper to the committee on public relations.

It was decided to publish the book *Geology of California* by R. D. Reed, at a pre-publication price of \$4.00 and a post-publication price of \$5.00.

W. E. Wrather was appointed editor of the book *Structure of Typical American Oil Fields*, Vol. III, to fill the vacancy caused by the death of Sidney Powers. The book is to be a memorial volume to Sidney Powers. The price is \$5.00 per copy.

It was decided to establish a Sidney Powers Memorial Publication Fund to be used for the issuance of further publications of value to the science of petroleum geology. Profits from the sale of the memorial volume and direct contributions as expression of appreciation of the work of Sidney Powers will be placed in this fund.

The price of the *Bulletin* cloth-bound volume for 1932 (ready in February,

1933) was fixed at \$4.00 to paid-up members, associates, and subscribers. This is a decrease of \$1.00 from the price for the 1931 volume.

The size of the monthly *Bulletin* is to be maintained during 1933, with no decrease in number of pages.

HOUSTON MEETING, MARCH 23-25, 1933

The eighteenth annual meeting of the Association will be held at the Rice Hotel, Houston, Texas, on March 23, 24, and 25. It is being planned to hold all sessions on the mezzanine of the headquarters hotel: main technical program, two division programs (paleontology and geophysics), and business meetings. The scientific exhibits will also be placed on this floor. Editor R. D. Reed, 929 South Broadway, Los Angeles, California, is arranging the technical program with the assistance of the associate editors and the local chairman of the technical program committee, Donald C. Barton, Petroleum Building, Houston.

Chairmen of the local committees on arrangements at Houston are as follows: general, Alexander Deussen, 1606 Post Dispatch Building; technical, D. C. Barton, Petroleum Building; finance, Ben C. Belt, Gulf Production Company; reception, George Sawtelle, Kirby Petroleum Company; entertainment, J. R. Suman, 919 Humble Building; registration, J. B. Eby, Box 962; exhibits, P. B. Hunter, Shell Petroleum Corporation; publicity, M. A. Hanna, Gulf Production Company; trips, L. P. Teas, Humble Building; golf, J. S. Ivy, United Gas System; ladies' entertainment, Mrs. D. C. Barton.

Transportation expense will be exceptionally low this year, many railroads already having in effect special rates on the basis of fare and a third for the round trip. Railroad certificates will be mailed as usual, but members should ask local ticket agents for lowest rate, as special excursions may be available in some areas.

Field trips are being planned by bus to the Conroe field, and to Sugarland and Boling sulphur mine, or New Gulf in Wharton County.

The usual announcement and reservation cards for hotel and entertainment will be mailed to each member in February.

Titles of papers and abstracts not already submitted, together with information on number of double-spaced typewritten pages in manuscript, time desired for presentation at meeting, number of illustrations (slides or charts), et cetera, should be in the hands of editor Reed before March 1, with duplicates to Association headquarters, Box 1852, Tulsa, Oklahoma, for inclusion in the printed program.

Members submitting complete manuscripts prior to the meeting are requested to submit two or three duplicates for use in soliciting discussions to be prepared in advance of the meeting.

Titles, abstracts and manuscripts for the Division of Paleontology should be sent to Merle C. Israelsky, chairman of the program committee for the Society of Economic Paleontologists and Mineralogists, Rusk Building, Houston; titles, abstracts and manuscripts for the Division of Geophysics, to L. W. Blau, chairman for the Society of Petroleum Geophysicists, Humble Oil and Refining Company, Houston, Texas.

The following titles of papers have been submitted for the technical program. This is a partial and preliminary list.

- "Studies in Paleogeology," by A. I. Levorsen
- "Raccoon Bend Field, Texas," by L. P. Teas
- "Possible Rôle of Diastrophism in Topography of Corpus Christi Area, South Texas," by W. Armstrong Price
- "Rôle of Deflation in Origin of Playas and Salt-Dome Basins," by W. Armstrong Price
- "Geology of Potter and McKean Counties, Pennsylvania," by H. Rogers Van Gilder
- "Earth Temperatures in Relation to Geology," by C. E. Van Orstrand
- "Mississippian of Colorado," by J. Harlan Johnson and Arthur E. Brainerd
- "Permo-Carboniferous of Colorado," by J. Harlan Johnson
- "Zone of *Exogyra Cancellata* Traced Twenty-Five Hundred Miles," by L. W. Stephenson
- "Some Structural Features of Trans-Pecos Texas," by P. B. King
- "Relation of Ouachita Geosyncline to Oil and Gas Fields of Mid-Continent Region," by H. D. Miser
- "Preliminary Study of Source Beds of Four Oil-Producing Regions—Santa Fe Springs, California; Salt Creek, Wyoming; Central Oklahoma; and East Texas," by P. D. Trask
- "Preliminary Study of Source Beds in Mesozoic Rocks on West Side of Sacramento Valley, California," by P. D. Trask
- "Origin of Miocene Siliceous Rocks of California," by M. N. Bramlette
- "Pennsylvanian Salt-Bearing Paradox Formation of Eastern Utah and Western Colorado," by A. A. Baker, C. H. Dane, and J. B. Reeside, Jr.
- "Structure of Southeastern Utah," by A. A. Baker and C. H. Dane
- "Oil-Bearing Pliocene Beds of Southern California," by R. D. Reed
- "Surface Fracture System of Duval County, Texas," by D. C. Barton
- "Overhang on Salt Domes of Gulf Coast," by S. A. Judson
- "Circulation of Underground Waters," by O. E. Meinzer
- "Jackson of Gulf Coast," by Alva C. Ellisor
- "Review of Developments in Gulf Coast," by J. Brian Eby
- "Variation in Character of Salt and Cap from Dome to Dome in Gulf Coast," by A. G. Wolf and M. A. Hanna
- "Gulf Coast Geosyncline," by D. C. Barton
- "Pettus Sand in Southwest Texas," by Al Ferando
- "Results of Plug-Back Work in Salt Flat Field, Caldwell County, Texas," by R. E. Watson
- "Carolina-Texas and Laurel Fields, Webb County, Texas," by Don Danvers and Olin G. Bell
- "Driscoll Ranch Pool, Duval County, Texas," by I. R. Shelton
- "Yegua, Jackson, and Catahoula Formations from Fayette to Trinity County, Texas," by B. Coleman Renick
- "Value of Gas Conservation and Efficient Use of Natural Water Drive as Demonstrated by Laboratory Models," by H. D. Wilde, Jr.
- "Study of Bottom-Hole Pressures in East Texas Fields," by D. M. Colliwood and F. E. Heath

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Memorial

ULYSSES S. GRANT

Professor Ulysses S. Grant, head of the department of geology and geography at Northwestern University, died in Evanston, Illinois, September 21, 1932. His death came unexpectedly after a surgical operation. A short time before, Dr. Grant had been engaged in his usual activities, attending to various details of his well-known field course in the Lake Superior district and engaging in instructional work there. On his return he had been occupied in routine matters incident to the opening of the University. In this manner he was completing his thirty-third year in the service of the University. Surviving members of his family, residing in Evanston and elsewhere, are: Mrs. U. S. (Avis Winchell) Grant; Addison Winchell, Lois, Avis Harriet (Mrs. E. E. Swick), and Willard Winchell Grant.

Professor Grant, a native of Illinois, came to Northwestern in 1899 to occupy the William Deering Chair in Geology. His undergraduate training had been completed at the University of Minnesota and his doctorate was awarded by Johns Hopkins University in 1893. Prior to his coming to Northwestern he served on the Geological Survey of Minnesota, and for one year was a member of the faculty of the University of Minnesota.

At the time of his coming to Northwestern he was an associate editor of the *American Geologist*, and he continued in that capacity for several years after his teaching duties began. At one time, also, he was engaged by the Wisconsin Geological and Natural History Survey to investigate the lead and zinc deposits in the southwestern part of that state. The results of his studies in that field were presented in a number of State bulletins and in the Lancaster-Mineral Point Folio of the United States Geological Survey. As geologist in the employ of the latter organization he made several trips to Alaska, chiefly to study the mineral deposits in the Kenai Peninsula and the glaciers of Prince William Sound. Many of the glaciers of that vicinity bear names that were assigned by Dr. Grant and his associates at that time.

Other western fields, including parts of Wyoming and Oregon, were studied by Dr. Grant in the course of later work for the Federal Survey and for the Oregon State Bureau of Mines. He also had connection with the State Geological Survey of Illinois, largely in an advisory capacity. In the University he was called upon by his colleagues to act as dean of the College of Liberal Arts, on two occasions, one of them notably during the difficult period of the World War. For many years he was a member of various important committees of the faculty and was serving the University in that way at the time of his death.

Fitting tributes in recognition of Dr. Grant's high character and of his preëminent qualities as scientist and teacher have appeared in recent testimonials elsewhere. One characteristic, mentioned as often as any other, probably, was his passion for teaching in the field. His deep convictions concerning the efficacy of out-door instruction were expressed in his scrupulous prepara-

tion for all field excursions. His physical vigor and tireless interest during the progress of any trip served to put younger men on their utmost mettle. His knowledge of birds and trees, presented with a sympathetic interpretation of the geography and historical background of a region, made his a companionship that was sought ardently by non-geological lovers of the open fields. Occasionally, for example, his early interest in zoölogy would find echo in his comments on the molluscan life of some swamp.

Early in his administration a definite field policy was inaugurated and consistently developed through the following years. So regular was his routine of field trips that citizens in various regions of Illinois, Wisconsin and Minnesota learned to have a proprietary interest in him and his visits.

His associates learned that the regions of his earlier work in geology were the places that Dr. Grant loved best to visit with his students. This was due wholly to his concern that the fullest benefits might accrue to those taking trips with him. The paths that led directly to the geological heart of a locality were the beaten paths for Dr. Grant. He had a deep disinclination for spending any time in a field that might be time lost for the student. For that reason those who have been with him in northern Illinois, in southern Wisconsin, or in northeastern Minnesota, will ever enjoy a full sense of companionship and scholastic profit in revisiting places where he once led them.

Dr. Grant's relationships with the members of his department and with the entire faculty group were so genial and harmonious that all feel a sense of loss wholly beyond any expression in mere words. His was an influence that will be ever-abiding.

JOHN R. BALL

NORTHWESTERN UNIVERSITY
December, 1932

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

CARL F. BEILHARZ, formerly of Chickasha, Oklahoma, is now resident geologist for The Pure Oil Company at Guedan, Louisiana.

W. DOW HAMM, geologist for the Shell Petroleum Corporation, has moved from Dallas to Houston, Texas.

ARNOLD S. BUNTE is exploitation engineer for the Shell Petroleum Corporation, Houston, Texas.

MARK C. MALAMPHY, geophysicist for Servico Geologico e Mineralogico do Brazil, Rio de Janeiro, has written a series of papers on "Argentine Petroleum Industry and the Effects of the Nationalization Policy." The first of the series is contained in the December 26, 1932, issue of *The Oil Weekly*.

F. MABRY HOOVER, formerly of Ardmore, may now be addressed at the Empire Oil and Refining Company, Box 1163, Oklahoma City, Oklahoma.

ROBERT H. DOTT, president of the Tulsa Geological Society, presented his presidential address, "Structural History of the Arbuckle Mountains," at the regular annual meeting, January 9, 1933.

ANGUS McLEOD, geologist for the Shell Petroleum Corporation, and formerly of Dallas, Texas, is now located at Houston.

R. VAN A. MILLS, vice-president and general manager of the Hudson's Bay Oil and Gas Company, Calgary, Alberta, Canada, has been appointed chief production engineer for the Continental Oil Company at Ponca City, Oklahoma. Mr. Mills will retain his position with the Hudson's Bay Company, and direct its activities from Ponca City.

FREDERICK S. LOTT is geologist and engineer for Brokaw, Dixon, Garner and McKee, 120 Broadway, New York City. He may be addressed at 20 MacKay Place, Brooklyn, New York.

LAVERNE DECKER, consulting geologist of Marshall, Texas, has a paper in the January 5, 1933, issue of the *Oil and Gas Journal*, entitled "Geology and Possibilities of Oil in Large Area Northeast of the Defined East Texas Field."

The Fort Worth Geological Society has elected the following officers for the coming year: president, WALTER R. BERGER, consulting geologist; vice-president, R. H. FASH, Fort Worth Laboratories; secretary-treasurer, LEWIS C. ROBERTS, Stanolind Oil and Gas Company.

WILLIAM B. HERoy, of the Sinclair Exploration Company of New York, and secretary-treasurer of the Association, was in the Gulf Coast and Mid-

Continent regions in December, and spoke on Association activities before the Houston Geological Society and the Tulsa Geological Society.

HENRY N. TOLER, consulting geologist, Drawer 546, Jackson, Mississippi, has been working for the Mississippi State Oil and Gas Board.

MERLE F. GUNBY, Box 1014, Houston, Texas, associated with T. J. Darby of Houston, has been working in Southwest Texas and the Gulf Coast.

ARTHUR GRAY LEONARD, professor of geology at the University of North Dakota and state geologist for thirty years, died at his home in Grand Forks on December 17, 1932.

DONALD F. MACDONALD is teaching at St. Francis Xavier University, Antigonish, Nova Scotia.

HANS STILLE, formerly of the Geological Institute at Göttingen, is director of the Institute of Geology and Paleontology of the University of Berlin.

Microscopists and others interested in petrographic studies may obtain Leitz Bulletin No. 5, "Refractive Index Determinations of Minerals" (8 mimeographed pages), and Leitz Bulletin No. 7, "New Accessories for the Universal Method," by addressing E. Leitz, Inc., 60 East Tenth Street, New York City.

The Geological Society of Chicago was organized, December 12, by the geologists of Greater Chicago. Professors EDSON S. BASTIN and JOHN R. BALL spoke in honor of the late Professor U. S. GRANT. Professor WARREN J. MEAD, of the University of Wisconsin, spoke on the subject "The Hoover Dam." Seventy men and women representing the petroleum companies, museums, and universities of Greater Chicago attended.

The Tulsa Geological Society has elected the following officers for 1933: president, IRA H. CRAM, Pure Oil Company; first vice-president, JOHN L. FERGUSON, Amerada Petroleum Corporation; second vice-president, E. F. SHEA, Stanolind Oil and Gas Company; secretary-treasurer, STANLEY B. WHITE, Box 981, Mid-Kansas Oil and Gas Company; members of the council, ROBERT M. WHITESIDE, R. B. RUTLEDGE, and LUCIAN H. WALKER.

The Kansas Geological Society elected the following officers at the December meeting of the society: president, N. W. BASS, U. S. Geological Survey; vice-president, E. C. MONCREIF, Derby Oil Company; and secretary-treasurer, L. R. FORTIER, Shell Petroleum Corporation; all of Wichita, Kansas. R. A. WHORTAN was elected director for a two-year term.

The Rocky Mountain Association of Petroleum Geologists at Denver, Colorado, has elected the following officers for 1933: president, A. E. BRAINERD, Continental Oil Company; vice-president, H. F. DAVIES, The California company; vice-president, J. G. BARTRAM, Stanolind Oil and Gas Company; secretary-treasurer, G. G. LAW, U. S. Geological Survey.

At their last regular meeting held January 11, the members of The Charleston Geological Society changed the name of their organization to The

Appalachian Geological Society. This action was taken with the object in view of covering a larger territory for membership. The following officers were elected for the year 1933: president, C. D. HUNTER, Kentucky-West Virginia Gas Company, Ashland, Kentucky; vice-president, H. E. CRUM, Columbian Carbon Company, Charleston, West Virginia; and O. FISCHER, P. O. Box 1375, Charleston, West Virginia.

DOUGLAS A. GREIG, formerly of London, England, has accepted a position with the Standard Oil Company of New Jersey, as geologist for the Società Petroliera Italiana in Western Italy. His address is Formovo-Taro (Parma), Italy.

The West Texas Geological Society elected the following officers at a meeting held in San Angelo, January 10: president, ROBERT F. IMBT, consulting geologist, San Angelo; vice-president, CHARLES D. VERTREES, Continental Oil Company, Midland; secretary-treasurer, MISS MINETTE RIES, Phillips Petroleum Company, Midland, Texas.

FANNY C. EDSON, stratigrapher for the Shell Petroleum Corporation, and IRA H. CRAM, division geologist for the Pure Oil Company, both of Tulsa, were elected Fellows of the Geological Society of America at their recent meeting. Mrs. Edson is the seventh woman in the world to be so honored.

LESLIE A. FISHER, geologist for the Sinclair Prairie Oil Company, and formerly of Tyler, has been transferred to Fort Worth, Texas.

W. T. NIGHTINGALE, geologist for the Ohio Oil Company at Los Angeles, addressed the Northwest Oil and Gas Association at their convention in Seattle, January 12-14, on the "Oil Possibilities of Certain Districts near Aberdeen and Hoquiam."

H. SMITH CLARK, geologist, Sinclair Prairie Oil Company, has been transferred from Tyler to Conroe, Texas.

HUBERT E. BALE, NOEL EVANS, and WARREN B. WEEKS, constitute the firm of consulting geologists, Bale, Evans, and Weeks, 701 Continental Building, Oklahoma City, Oklahoma.

A. I. LEVORSEN spoke before a meeting of the Tulsa Geological Society, Monday evening, January 23, on "Studies in Paleogeology."

